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Would a ‘Modest Policy Intervention’ Have Prevented the U.S. Housing Bubble?*

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Abstract

A ‘modest policy intervention’ in which the Federal Funds rate had reacted, *weakly but systematically*, to the ratio between house prices and rents would have prevented the building up of the housing bubble which pre-dated the Great Recession, at a small cost in terms of real activity. Monetary policy shocks, which I identify by combining zero and sign restrictions, cause strongly statistically significant decreases in real house prices, housing starts, hours worked in construction, and loans to the real estate sector, and a statistically significant temporary *increase* in the real rent.

Keywords: Bayesian VARs; structural VARs; monetary policy; zero restrictions; sign restrictions; housing market; Great Recession; counterfactuals.

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1 Introduction

The role played by the Federal Reserve's monetary policy within the context of the housing bubble which pre-dated the Great Recession has been the subject of an intense debate. On the one hand, Taylor (2009) has argued that an excessively loose monetary policy—with the extent of looseness being measured in terms of deviations of the Federal Funds rate from the path implied by a standard Taylor (1993) rule—had played a crucial role in igniting the bubble. On the other hand, the FED has consistently rejected such a position, with Bernanke (2010, p. 19) concluding that the linkages between the housing bubble and the FED's monetary policy stance during the years pre-dating the financial crisis 'are weak'.[1]

In this paper I explore whether an alternative monetary policy during the years leading up to the financial crisis—in particular, a policy in which the FED Funds rate had systematically reacted to a simple measure of disequilibrium in real house prices—could have prevented the building up of (all or most of) the house prices bubble, and what the cost of such a policy would have been in terms of real activity. My main finding is that a deviation from the FED's historical pattern of behaviour so small as not to be detectable by economic agents, thus not triggering any change in their expectations, could indeed have prevented the building up of most of the bubble, and would have essentially eliminated the disequilibrium by the Summer of 2007, when, historically, the financial crisis started.[2] Further, such a policy would have entailed quite limited costs in terms of real activity.

Both academics, and especially central bankers, are typically loth to using monetary policy in order to lean against an asset price bubble, and usually favor so-called 'macro-prudential policies', specifically designed in order to surgically target disequilibria in specific asset markets' segments. A main point of this paper is that, although there are indeed very strong logical and theoretical reasons for preferring such a targeted approach, some of the arguments which are routinely made against using interest rates to lean against asset price bubbles are not supported by solid empirical evidence. A commonly heard argument, for example, is that such an approach would be 'too blunt', and that it would therefore inevitably entail a significant 'collateral damage' in terms of real activity.[3] As I show in this paper, this argument is not based on solid evidence. Another oft-mentioned argument is the U.S. stock-market's shrugging of Alan Greenspan's threat of using the FED Funds rate to lean against stock prices in his famous 'irrational exuberance' speech. In fact, as discussed by Kindleberger and Haliber (2005),[4] this episode is just an illustration of the ineffectiveness of non-credible threats: since such an approach had never been implemented

[1] As for the empirical evidence underlying Bernanke's speech, see in particular Dokko, Doyle, Kiley, Kim, Sherlund, Sim, and VanDenHeuvel (2011).

[2] The starting date of the financial crisis is traditionally taken to be August 2007, when the European Central Bank started massively intervening in Euro area money markets.

[3] See e.g. Dokko, Doyle, Kiley, Kim, Sherlund, Sim, and VanDenHeuvel (2011).

[4] See page 94.

over the entire post-WWII period—and, when it had been implemented towards the end of the 1920s, it had led to a stockmarket collapse—Greenspan's threat lacked credibility, and in fact it was duly ignored. The experience of the 1920s is often cited as a cautionary tale about the catastrophic dangers of using monetary policy in order to lean against asset prices' disequilibria. Following the stockmarket's ignoring of warnings about its overvaluation on the part of the Chairman of the Federal Reserve Board, the FED embarked upon a series of interest rates' increases, which ultimately led to the 1929 stockmarket crash. An alternative reading of the experience of the 1920s, however, is that it is a classic example of the 'boom and bust' dangers associated with a 'go-stop' monetary policy. According to this interpretation, the FED first ran, during the years leading up to the crisis, an excessively loose monetary policy,[5] which either inflated or tolerated the rising of bubbles in stocks and real estate prices. Then, starting in 1928, it panicked and reversed course, hiking interest rates and then ultimately causing the crash. According to this view, the 1929 stockmarket crash represents a cautionary tale against following such an erratic monetary policy, rather than an indictment of using monetary policy to lean against asset prices' bubbles.

In this paper I consider a completely different type of policy intervention, in which a subset of the parameters of the Federal Reserve's structural monetary policy rule within an estimated VAR is perturbated in such a way that the FED Funds rate exhibits a *weak, but systematic* reaction to a simple indicator of disequilibrium in real house prices, i.e., the ratio between house prices and rents. I show that within the set of perturbations which can be regarded as 'modest' in the sense of Leeper and Zha (2003)—and therefore such as not to induce economic agents to revise their expectations, which would cause the Lucas critique to 'bite', and would therefore render the entire experiment irrelevant—it is possible to find perturbations which would have prevented the building up of most of the bubble, and would have eliminated it by the Summer of 2007, at a comparatively small cost in terms of real activity. For example, a modest intervention such as to generate an alternative path for the FED Funds rate leading to counterfactual real house prices being, in the Summer of 2007, about 14 per cent lower than they actually were, would have caused an increase in the unemploymement rate by about 0.8 percentage points. One of the reasons behind my results is that house prices are quite significantly more sensitive to interest rate movements than either GDP or the unemployment rate. In particular, results from structural VARs—which I identify by combining elements of Sims and Zha (2006), Leeper and Roush (2003), and Arias, Caldara, and Rubio-Ramirez (2014)—suggest that a 25 basis points contractionary shock to the FED Funds rate leads to a maximum response of about -42 basis points for real house prices, and only of about 4 basis points for the unemployment rate. As a result, a policy intervention which is sufficiently aggressive to tame house prices will have, in

[5] See e.g. Eichengreen (2015). The argument that the FED's monetary policy during the first part of the 1920s had been excessively loose was originally made, e.g., by Lionel Robbins (1934).

general, a more subdued impact on real activity.

With the benefit of hindsight, trading off a 14 per cent reduction in real house prices (i.e., no bubble) with an increase in unemployment of less than one per cent would appear as an obvious choice, especially in the light of the disastrous consequences wreaked by the unravelling of the housing bubble. In real time (i.e., as the bubble was inflating), things were, in fact, much less clear-cut. In Benati (2015), e.g., I show that a SVAR-based methodology which, based on the full sample up to the end of 2014, robustly identifies a large, transitory deviation of real house prices from their stochastic trend for the years pre-dating the crisis, exhibits a much worse performance based on *real-time* data. Further, it is important to recall how the unravelling of neither of the two previous large disequilibria in post-WWII U.S. real house prices (in the second halves of the 1970s and 1980s, respectively) had caused catastrophic recessions.[6] This means that, from the perspective of the Federal Reserve operating in real time during the years leading up to the crisis, the decision on whether to pursue a policy of 'marginally leaning against the housing bubble' would have been much less obvious than the results from my counterfactual experiments might seem to suggest.

Before proceeding further, let me briefly recapitulate what this paper *does* say, and what it *does not* say:

first, this paper does argue that a modest policy intervention could have prevented the housing bubble which pre-dated the financial crisis at a comparatively small cost in terms of real activity. However,

second, by no means it claims that a lax monetary policy was the key underlying cause of the U.S. housing bubble. Quite simply, there is no logical connection between these two statements.

Third, by no means the paper argues that the best way to tame asset prices disequilibria is *via* a monetary policy of 'leaning against the bubble'. On the contrary, as discussed e.g., by Bernanke (2010), there are very strong logical and conceptual reasons for preventing asset prices bubbles *via* a more targeted approach based on macro-prudential policies.[7]

[6] The second episode was followed by the comparatively mild recession of the early 1990s. As for the first one, it was followed by the 'Volcker recession', with the unemployment rate reaching a post-WWII peak of 10.8 per cent in the last two months of 1982. It has to be stressed, however, that Paul Volcker's contractionary monetary policy is near-universally regarded as the dominant cause of the disinflation of the early 1980s and of the associated deep recession, whereas, to the very best of my knowledge, no researcher has ever ascribed to the bursting of the housing bubble of the second half of the 1970s an important role in causing the 'Volcker recession'.

[7] As he pointed out (on page 20),

> 'the best response to the housing bubble would have been regulatory, not monetary. Stronger regulation and supervision aimed at problems with underwriting practices and lenders' risk management would have been a more effective and surgical approach to constraining the housing bubble than a general increase in interest rates. Moreover, regulators, supervisors, and the private

A key point this paper makes is simply that, in fact, monetary policy *could* have been used to tame the housing bubble, and that 'ineffectiveness', or 'being too blunt an instrument' for such a purpose, are not meaningful or solid counterarguments to having monetary policy reacting to housing market disequilibria. Another way of stating this is that macroprudential policies should be advocated based on argument more solid than 'using interest rates to lean against an asset price bubble just doesn't work', or 'the by-product of such an approach is to wreak the economy'. Since a policy of weakly, but systematically reacting to an asset price disequilibrium such as that analyzed in this paper has never been tried anywhere, the notion that it cannot work is simply not supported by any available empirical evidence.

The paper is organized as follows. The next section discusses the structural VAR methodology I use, whereas Section 3 presents evidence on the reliability of the estimated structural VARs. Section 4 presents results from the counterfactual experiments, whereas Section 5 explores the issue of whether such policy interventions can be regarded as 'modest' in the sense of Leeper and Zha (2003). Section 6 concludes.

2 Methodology

In what follows I will work with the VAR(p) model

$$Y_t = B_0 + B_1 Y_{t-1} + ... + B_p Y_{t-p} + u_t, \qquad E[u_t u_t'] = \Omega \tag{1}$$

where Y_t features (in this order) the logarithms of either M_2 (in the baseline specification) or non-borrowed reserves, the commodity price index, nominal house prices, nominal rents, and nominal loans to real estate; the Federal Funds rate; the logarithms of housing starts and hours in construction over population; the unemployment rate; and the logarithms of Stock and Watson's (2012) monthly interpolated real GDP and of the core personal consumption expenditure (henceforth, PCE) deflator. The series included in the baseline specification are shown in Figure 1. The sample period is January 1963-July 2007. The beginning of the sample period is dictated by the availability of the series for nominal house prices. I end the sample in July 2007 in order to prevent my results from being distorted by the financial crisis.

2.1 Estimation

The VAR is estimated *via* Bayesian methods as in Uhlig (1998, 2005). Specifically, Uhlig's approach is followed exactly in terms of both distributional assumptions—the distributions for the VAR's coefficients and its covariance matrix are postulated

sector could have more effectively addressed building risk concentrations and inadequate risk-management practices without necessarily having had to make a judgment about the sustainability of house price increases.'

to belong to the Normal-Wishart family—and of priors. For estimation details the reader is therefore referred to either the Appendix of Uhlig (1998), or to Appendix B of Uhlig (2005). Results are based on 100,000 draws from the posterior distribution of the VAR's reduced-form coefficients and the covariance matrix of its reduced-form innovations (the draws are computed exactly as in Uhlig (1998, 2005)). I set the lag order to p=6.[8]

2.2 Identification of the monetary policy shock

In line with Arias, Caldara, and Rubio-Ramirez (2014), I identify the monetary policy shock by combining zero and sign restrictions *via* the methodology introduced by Arias, Rubio-Ramirez, and Waggoner (2014). Specifically, monetary policy shocks are identified based on the restrictions that

(*i*) the Federal Funds rate does not react contemporaneously to any housing market variable (that is, to either house prices, rents, loans to real estate, housing starts, or hours in construction).[9]

(*ii*) The Federal Funds rate is allowed to react contemporaneously to other macroeconomic variables. Specifically, the contemporaneous responses to GDP, the price level, commodity prices, and M_2 (or non-borrowed reserves) are restricted to be non-negative, whereas the response to the unemployment rate is restricted to be non-positive. The rationale behind these restrictions is extensively discussed by Arias, Caldara, and Rubio-Ramirez (2014).

(*iii*) In line with, e.g., Sims and Zha (2006) and Leeper and Roush (2003), monetary policy shocks are postulated to have no impact at t=0 on either GDP, the unemployment rate, or the PCE deflator (on the other hand, the response of either variable at all other horizons is left unrestricted). As for housing market variables, I impose an analogous zero restriction on impact for hours in construction and housing starts (i.e., for real activity indicators), whereas I leave unrestricted the impact responses of house prices, rents, and loans to real estate. As we will see, neither house prices nor loans to real estate exhibit a statistically significant response to monetary policy shocks on impact, so that for these two series I might as well have imposed a zero restriction. Rents, on the other hand, experience a strongly statistically significant increase, which is uniformly robust across all of the specifications I consider, thus

[8]Results based on setting p=12 are qualitatively the same as those reported below, but, due most likely to the non-negligible number of variables included in the VAR (eleven), some of the impulse-response functions exhibit a somehow 'jagged' profile. As a consequence, I tend to prefer the set of results obtained by setting p=6. The entire set of results is however available upon request.

[9]Allowing for a contemporaneous reaction of the Federal Funds rate to housing market variables, but leaving such reaction unrestricted, produces qualitatively the same results reported herein (this alternative set of results is available upon request). On the other hand, I have not considered models in which the contemporaneous reaction of the Federal Funds rate to housing market variables is constrained to be either positive or negative, since, to the very best of my knowledge, there is no established consensus on what this reaction might or should be.

suggesting that the imposition of a zero restriction on impact would have distorted the inference.

(iv) Monetary shocks are postulated to cause an increase in the Federal Funds rate, and decreases in M_2 (or non-borrowed reserves) and commodity prices both on impact, and for at least 24 months after impact. As for the price level, I consider two alternative specifications: in the former I leave its response completely unrestricted at all horizons, whereas in the latter I rule out the price puzzle, by postulating that the response of the PCE deflator to monetary policy shocks be non-positive for at least 24 months after the impact. As I discuss below, for the purposes of this study the two specifications produce qualitatively the same, and quantitatively very close results, and in what follows I therefore mostly focus on the set of results produced by the specification which does *not* rule out the price puzzle.

The first three restrictions imply that, given the previously mentioned ordering of the variables (which is also reported in Figure 1); given the structural VAR form of (1), $Y_t = B_0 + B_1 Y_{t-1} + ... + B_p Y_{t-p} + A_0 \epsilon_t$, with $u_t = A_0 \epsilon_t$, which implies that $Y_t'[A_0^{-1}]' = [A_0^{-1}(B_0 + B_1 Y_{t-1} + ... + B_p Y_{t-p})]' + \epsilon_t'$; and assuming that the monetary policy shock, $\epsilon_{R,t}$, is the sixth disturbance in ϵ_t, the matrix $[A_0^{-1}]'$ has the following structure:

$$[A_0^{-1}]' = \left[\begin{array}{ccccc|c|ccccc} 0 & 0 & 0 & 0 & 0 & \leq 0 & x & x & x & x & x \\ 0 & 0 & 0 & 0 & 0 & \leq 0 & x & x & x & x & x \\ 0 & 0 & 0 & 0 & 0 & 0 & x & x & x & x & x \\ 0 & 0 & 0 & 0 & 0 & 0 & x & x & x & x & x \\ 0 & 0 & 0 & 0 & 0 & 0 & x & x & x & x & x \\ 0 & 0 & 0 & 0 & 0 & \geq 0 & x & x & x & x & x \\ \cline{1-5} x & x & x & x & x & 0 & x & x & x & x & x \\ x & x & x & x & x & 0 & x & x & x & x & x \\ x & x & x & x & x & \geq 0 & x & x & x & x & x \\ x & x & x & x & x & \leq 0 & x & x & x & x & x \\ x & x & x & x & x & \leq 0 & x & x & x & x & x \end{array} \right] \tag{2}$$

where x is an unrestricted non-zero entry, thus implying that the sixth column of $[A_0^{-1}]'$ features the contemporaneous elements of the VAR's structural monetary policy rule. The fact that the upper left (6×5) block of $[A_0^{-1}]'$ only contains zero entries automatically implies that the lower right (5×6) block of the structural impact matrix A_0 is, likewise, a block of zeros. In turn, this implies that the sixth column of A_0—i.e., the one corresponding to the monetary shock—is given by

$$\left[\begin{array}{ccccccccccc} x & x & x & x & x & x & 0 & 0 & 0 & 0 & 0 \end{array} \right]' \tag{3}$$

so that, on impact, the shock does not affect either real GDP, the unemployment rate, the PCE deflator, housing starts, and hours in construction.

The set of restrictions on $[A_0^{-1}]'$ described in (2), together with the restrictions discussed in point (iv) on the signs of the relevant impulse-response functions (henceforth, IRFs), can be efficiently implemented *via* the algorithm for combining zero and sign restrictions described by Arias, Rubio-Ramirez, and Waggoner (2014). For either of the draws from the posterior of the VAR's reduced-form coefficients, I consider a single random rotation matrix implementing the zero restrictions on $[A_0^{-1}]'$, which I generate *via* Arias *et al.*'s (2014) Algorithm 5.[10] Then, if the sign restrictions on both the contemporaneous coefficients of the VAR's structural monetary rule, and the relevant IRFs, are all satisfied, I keep the draw for the resulting structural VAR. Otherwise, I discard it. For the baseline specification including M_2 and not ruling out the price puzzle inference is based on about 12,000 successful draws. From now on, I will use the word 'draw' as a shorthand for 'successful draw', that is: a draw for which all of the zero and sign restrictions have been satisfied, and which I have therefore kept.

The next two sections discuss evidence on the response of the economy to identified monetary policy shocks, and on the importance of these shocks in driving macroeconomic fluctuations. To anticipate, all of my evidence pertaining to real activity indicators, prices, monetary aggregates, and commodity prices is in line with the corresponding results produced by, e.g., Sims and Zha (2006), Leeper and Roush (2003), and Arias, Caldara, and Rubio-Ramirez (2014).

The online appendix contains additional evidence which I here only discuss very briefly for reasons of space. Specifically, Figure A.4 and A.25 show the posterior distributions of the contemporaneous coefficients in the VAR's structural monetary rule (that is: the non-zero elements of the sixth column of the matrix $[A_0^{-1}]'$, based on models with M_2 and non-borrowed reserves, respectively. Figures A.5 and A.6 show, for models featuring M_2 and either allowing or ruling out the price puzzle, respectively, the medians of the posterior distributions of the differences between the counterfactual paths for the series obtained by killing off the identified monetary policy shocks and the series' actual, historical paths, together with the 16-84 and the 5-95 percentiles. Figures A.23 and A.24 show the same objects, but based on models including non-borrowed reserves, instead of M_2. For the entire sample period, and based on either of the four specifications considered herein (featuring either M_2 or non-borrowed reserves, and either ruling out, or not ruling out the price puzzle), killing off identified monetary policy shocks does not produce statistically significant counterfactual paths for either of the eleven variables included in the VAR. This is in line with the evidence on the fractions of forecast error variance of individual series explained by monetary policy shocks I will discuss in Section 4 below: as we will see, identified monetary shocks play an uniformly modest role in driving fluctuations in either series.

[10]See Arias *et al.* (2014) p. 18 (the version of the paper I am referring to is dated September 7, 2014). Notice that although Arias *et al.*'s paper discusses a more general algorithm based on Gibbs-sampling, as they point out *'[...] when the researcher is interested in identifying only one shock, the Gibbs sample step in Algorithm 4 is not necessary, and one should obtain q from Algorithm 5.'*

3 Are the Identified Monetary Policy Shocks Plausible?

This paper's main focus will be a series of counterfactual experiments in which the FED's structural monetary policy rule is perturbated in such a way that the FED Funds rate exhibits some mild reaction to deviations of the price-rent ratio from its historical, pre-January 1995 average. Before proceeding with these counterfactuals, however, it is important to ascertain, as a preliminary robustness check, whether the identified monetary policy shocks exhibit properties in line with those which have been previously established in the literature on monetary VARs. If that were not the case, this would obviously raise doubts on the reliability of the VARs I am working with, and, by extension, it would call into question the meaningfulness of any additional experiment I might perform, including counterfactual simulations. In this section I therefore explore whether the identified shocks possess properties in line with those found in the literature, focusing on impulse-response functions and variance decompositions. To anticipate, evidence clearly suggests that this is indeed the case.

3.1 Impulse-response functions

Figure 2 reports the IRFs to a contractionary monetary policy shock based on the model with M_2 and not ruling out the price puzzle, whereas figure A.2 in the online appendix reports the corresponding IRFs based on the model ruling out the price puzzle both on impact, and for the subsequent 24 months. Figures A.19 and A.20 report results for the models with non-borrowed reserves. IRFs have been normalized in such a way that the median impact on the Federal Funds rate at t=0 is equal to 25 basis points (in all figures the scale is in percentage points). The following main features ought to be stressed of the overall set of results:

first, the baseline evidence for GDP, the unemployment rate, and the PCE deflator shown in Figure 2 is qualitatively and quantitatively in line with the corresponding results reported, e.g., by Sims and Zha (2006, Figure 2). A contractionary monetary policy shock causes a statistically significant, hump-shaped transitory increase in the unemployment rate and a corresponding statistically significant U-shaped transitory decrease in real GDP. In particular, based on median estimates, a 25 basis points contractionary shock to the FED Funds rate causes, about two years and a half after the impact, a peak increase in unemployment equal to 4 basis points, and a maximum decrease in GDP of -14 basis points,[11] with an implied 'Okun coefficient'

[11] A precise comparison with the results reported in Sims and Zha's (2006) Figure 2 is not entirely straightforward, since they did not normalize monetary shocks in any way. The impact of monetary shocks on the FED Funds rate at t=0 they report, however, was equal to about 0.0015, whereas the maximum impacts on GDP and the unemployment rate were equal to about -0.0011 and 0.0004. This means that my estimates are quite close, even from a quantitative point of view, to Sims and

linking changes in the transitory components of the two variables equal to about -3.5. As for the PCE deflator, the response is insignificant at all horizons after impact (compare with panel (3,2) of Sims and Zha's Figure 2). Ruling out the price puzzle produces a very similar response for GDP, whereas for the unemployment rate the response is now weaker, and it is significant only at the one-standard deviation level. Finally, models featuring non-borrowed reserves consistently produce comparatively weak and statistically insignificant responses for either GDP or the unemployment rate. Since this is in contrast with the results produced by the key papers in the literature on monetary VARs—see in particular Sims and Zha (2006), Leeper and Roush (2003), and Arias, Caldara, and Rubio-Ramirez (2014)[12]—in what follows I will almost exclusively focus on the results based on models featuring M_2.

Second, although both M_2 and the commodity price index strongly fall over the horizon for which their IRFs have been restricted, going forward they tend to mean-revert to zero uniformly across alternative specifications, so that their responses at horizons beyond two years ahead are typically not statistically significant at the 90 per cent level.

Third, as for housing market variables, the real rent exhibits a short-lived, highly statistically significant *increase*, which is uniformly robust across all of the alternative model specifications I consider. The response of the real house price, on the other hand, is statistically insignificant on impact, but it becomes significant, and quantitatively quite large, at horizons between three months and about five years after the impact. In particular, based on median estimates a 25 basis points contractionary shock to the FED Funds rate causes a maximum decrease in real house prices of -43 basis points about two years ahead.[13] As I discuss more extensively in Section 5 below, such a comparatively stronger sensitivity of real house prices to monetary policy plays an important role in allowing a modest policy intervention to materially affect the recent housing bubble in my counterfactuals, at only a modest cost in terms of real activity. Finally, evidence clearly suggests that the response of real house prices to monetary policy shocks is transitory, with house prices mean-reverting to zero at horizons beyond five years after the impact. The response of real loans to real estate is both qualitatively and quantitatively quite similar to that of real house prices, being statistically insignificant on impact; becoming highly significant three

Zha's.

[12] Uhlig (2005) estimated an increase in real GDP, following a contractionary monetary policy shock, with a probability equal to about one-third. Arias *et al.* (2014), however, argue that Uhlig's results are the figment of the highly implausible structural monetary policy rule which is implicit in his analysis.

[13] This response is somehow *weaker* than that found in previous studies, and exhibits a different time profile, being delayed and U-shaped, instead of 'front-loaded' and monotonically decreasing. Based on a dynamic factor analysis model identified *via* sign restrictions, for example, DelNegro and Otrok (2007) estimate the impact of a one-standard deviation (about 0.16) monetary shock on real house prices as equal to about -0.6 on impact, and monotonically converging to zero after that (see their Figure 5). Qualitatively and quantitatively very similar results are obtained by Iacoviello and Neri (2010) based on an estimated DSGE model of the U.S. housing market (see their Figure 3).

months after the impact; exhibiting a maximum decrease of -45 basis points about four years ahead; and mean-reverting to zero going forward. Finally, the responses of both housing starts and hours in construction point towards a recessionary impact of contractionary monetary policy on the real activity side of the housing market, with hours worked exhibiting a maximum decrease of -25 basis points two years and a half ahead. Ruling out the price puzzle in the model with M_2 produces qualitatively the same, and quantitatively very close IRFs for all housing market variables. Based on models featuring non-borrowed reserves, responses are qualitatively the same as based on M_2, but they are slightly weaker (e.g., the maximum decrease in real house prices is about minus four per cent).

3.2 Fractions of forecast error variance explained by monetary policy shocks

A robust, well known stylized fact about monetary policy shocks is that they typically explain very little of anything, including the central bank's monetary policy rate. This is also the case here. Figure 3 shows, for either series, the fractions of forecast error variance (henceforth, FEV) explained by monetary shocks at horizons up to ten years ahead, whereas Figure A.3 in the online appendix reports the same evidence for the model ruling out the price puzzle. Figures A.21 and A.22 report the corresponding set of results for the models including non-borrowed reserves.

The fractions of FEV from the baseline specification shown in Figure 3 are uniformly very low at all horizons for GDP, the unemployment rate, the PCE deflator, housing starts, hours in construction, and the rent; they are very small at shorter horizons, but slightly higher further out, for house prices and loans to real estate; they are non-negligible at the very short horizon, but consistently very small at longer horizons, for the FED Funds rate and commodity prices; and they are mostly small, but with a significant extent of uncertainty, for M_2. Results based on either of the three alternative specifications (with M_2, but ruling out the price puzzle; and with non-borrowed reserves) are both qualitatively and quantitatively in line with those reported in Figure 3.

4 Perturbating the Posterior Distribution of the FED's Structural Monetary Policy Rule

All of the results discussed so far suggest that the monetary policy shocks identified herein possess 'standard' properties, in line with the evidence produced by researchers such as Sims and Zha (2006), Leeper and Roush (2003), and Arias, Caldara, and Rubio-Ramirez (2014). This is reassuring, and it suggests that our monetary VARs might well be trusted with additional experiments beyond the computation of IRFs to monetary shocks. In this section I therefore proceed to this paper's main experiment, in which the posterior distribution of the FED's structural monetary policy rule is perturbated in such a way that the FED Funds rate exhibits some *weak, but systematic* reaction to deviations of the price-rent ratio from its pre-January 1995 mean (I discuss below the reasons for starting the counterfactuals in the mid-1990s).

In order to make the counterfactual experiments more transparent, I start by re-estimating the VARs, and imposing the identifying restrictions, exactly as before, with the *only* difference that in the vector Y_t in equation (1) I replace the logarithm of the nominal rent with the difference between log house prices and log rents, which I normalize in such a way that it is zero-mean over the period between January 1963 and December 1994. In the counterfactual simulations I will run for the period January 1995-July 2007, the central bank, by reacting to (the log of) the price-rent ratio, will in fact be reacting to its deviations from the pre-1994 mean, and will therefore implicitly treat such deviations as indications that the relationship between house prices and rents is departing from its long-run equilibrium. The rationale for doing this is that, as documented by Gallin (2008), and especially by Benati (2015), the relationship between house prices and rents is analogous to those between GNP and consumption, and between stock prices and dividends, explored by Cochrane (1994). In particular, in the same way as a positive (negative) deviation of the consumption/GNP ratio from its unconditional mean signals GNP being below (above) potential, a deviation of the price-rent ratio from its historical mean signals house prices having departed from their long-run, equilibrium value.[14]

Quite obviously, there are several other counterfactuals conceptually along the same lines a researcher might think of performing. A more realistic experiment, for example, would involve the FED Funds rate reacting to real-time estimates of the transitory component of real house prices, recursively computed (e.g.) as in Benati (2015), based on structural VAR methods. There are two main reasons why I have chosen to uniquely focus on the counterfactual experiment at hand. First, performing

[14] To be precise (I wish to thank Matteo Iacoviello for an helpful email exchange on this), a standard DSGE model with housing implies that, in equilibrium, the rent-price ratio ought to be equal to the real interest rate. Over the post-WWII period, however, the U.S. *ex post* real interest rate has been strongly stationary (e.g., the bootstrapped p-values for Elliot, Rothenberg, and Stock (1996) unit root tests for the U.S. *ex post* real interest rate reported in Table A.1 in the online appendix of Benati (2015) are uniformly below 0.1). This implies that, in the long-run, the rent-price ratio ought to be mean-reverting, so that deviations from its unconditional mean point towards the relationship between house prices and rents as being out of kilt. It is to be noticed that Elliot *et al.*'s (1996) tests do not allow to reject the null of a unit root in the log of the rent-price ratio (these results are available upon request). Within the context of the relationship between consumption and GNP, however, Cochrane (1994) cautioned against drawing the wrong inference from this kind of results. As he pointed out, since theory implies that consumption and GNP *ought* to be cointegrated with cointegration vector [1; -1], any lack of rejection of the null of a unit root in the consumption-GNP ratio should be regarded as a fluke (most likely due to the fact that fluctuations in the ratio are very highly persistent, so that in small samples it may well be confused with a unit root process). Exactly the same argument applies here to the ratio between rents and house prices, which in what follows I will therefore treat as I(0).

the more realistic counterfactual based on real-time data is problematic, as, of the eleven series entering the VARs I am using herein, real-time data are available only for a limited subset (in particular, real-time data are not available for three key housing market variables: loans to real estate, housing starts, and hours in construction). Second, the main goal of this paper is to show that the bulk of the U.S. housing bubble could have been prevented *via* a straightforward policy in which the FED Funds rate had reacted to a very *simple, but robust* indicator of disequilibrium in real house prices. To put it differently, I see the role played by this paper as mainly *illustrative* of the *basic concept*, rather than providing an analysis as realistic as possible of what the FED might have accomplished in real time.[15]

Let me now turn to the details of the perturbations of the posterior distributions of the parameters of the structural monetary policy rule which underlie the counterfactual simulations. In a nutshell, what I do is simply 'shifting upwards' by a very small amount the posterior distributions of the parameters on the ratio between house prices and rents in the structural monetary rule. This causes the FED Funds rate to become *marginally more aggressive* towards deviations of the price-rent ratio from its pre-1995 average. In turn this tends, in the associated counterfactual simulations, to 'cool them off', thus shrinking the size of the pre-Great Recession bubble. As we will see—I will show results from a set of perturbations of different magnitudes—in principle it is possible to engineer the perturbation in such a way that, essentially, it completely eliminates the bubble. So the key question becomes whether such a perturbation is, or is not a 'modest policy intervention' in the sense of Leeper and Zha (2003). As we will see in Section 5, this is indeed the case.

4.1 Details of the perturbations

Let $Y_t = B_{0,j} + B_{1,j}Y_{t-1} + ... + B_{p,j}Y_{t-p} + A_{0,j}\epsilon_t$ be the structural VAR associated with draw j from the posterior distribution, and let $Y_t'[A_{0,j}^{-1}]' = [A_{0,j}^{-1}(B_{0,j} + B_{1,j}Y_{t-1} + ... + B_{p,j}Y_{t-p})]' + \epsilon_t'$, that is,

$$Y_t'\tilde{A}_{0,j} = \tilde{B}_{0,j} + Y_{t-1}'\tilde{B}_{1,j} + ... + Y_{t-p}'\tilde{B}_{p,j} + \epsilon_t' \tag{4}$$

be its associated structural form, with $\tilde{A}_{0,j} \equiv [A_{0,j}^{-1}]'$ and $\tilde{B}_{k,j} \equiv [A_{0,j}^{-1}B_{k,j}]'$, k = 0, 1, 2, ..., p. Since, as previously mentioned, the sixth shock in ϵ_t is the monetary policy shock, this automatically implies that the sixth equation in (4) is the FED's structural monetary policy rule (see Arias *et al.*, 2014). In the baseline specification the FED Funds rate is postulated not to react contemporaneously to any housing

[15] Another possibility would be to just ignore the real-time data issue altogether, to recursively compute transitory components of real house prices based on the VAR as in Benati (2015), and then to perform the same modest policy intervention which is being performed herein, but having the FED Funds rate reacting to transitory house prices, rather than the price-rent ratio. Given the very strong correlation between the price-rent ratio and the transitory component of real house prices I computed in Benati (2015), I suspect that results would be very similar to those reported herein.

market variable, so that, for the purpose of the perturbation, only the coefficients on the lagged price-rent ratio in the structural monetary policy rule are relevant.[16] For draw j from the posterior, let these coefficients be defined as $\gamma_{l,j}$, for l = 1, 2, ..., p. For each draw j, and each l = 1, 2, ..., p, I perturbate the $\gamma_{l,j}$'s by rescaling them as

$$\gamma_{l,j}^{*} = \gamma_{l,j} + K \cdot |\gamma_{l,j}| \tag{5}$$

where $|\cdot|$ means 'absolute value of', and K is a 'small number'—in what follows, I consider four possible values: 0.005, 0.01, 0.015, and 0.02. In plain English, for each draw from the posterior, and for each lag, I increase the relevant coefficient by a small percentage amount, with the result that the entire posterior distributions of the $\gamma_{l,j}$'s are 'shifted upwards' by a small percentage amount. On the other hand, I leave all of the other coefficients in the structural monetary policy rule unchanged. Based on the resulting counterfactual (or 'perturbated') structural form, I then recover the corresponding counterfactual structural VAR for draw j, $Y_t = B_{0,j}^c + B_{1,j}^c Y_{t-1} + ... + B_{p,j}^c Y_{t-p} + A_{0,j}^c \epsilon_t$,[17] which I then use to re-run history from January 1995 up until July 2007 conditional on the previously identified structural shocks.[18] So it is worth stressing that, although in Section 5 I will investigate whether my counterfactuals can be regarded as 'modest policy interventions' in the sense of Leeper and Zha (2003), the type of interventions I am here considering are different from theirs: whereas they worked by manipulating the monetary policy shocks, I am here instead perturbating the structural monetary policy rule.

4.2 Why starting the counterfactuals in the mid-1990s?

There are two main reasons why I start the counterfactuals in the mid-1990s.

First, as stressed by several commentators, the housing bubble started in the second half of the 1990s. Bernanke (2010), for example, pointed out that

> '[house] prices began to rise more rapidly in the late 1990s. Prices grew at a 7 to 8 percent annual rate in 1998 and 1999, and in the 9 to 11 percent range from 2000 to 2003. [...] Shiller (2007) dates the beginning of the boom in 1998.'

Second, since I am here considering very small policy interventions—in particular, the interventions *ought* to be so small that they can be in fact regarded as 'modest',

[16] As previously mentioned, however, allowing the contemporaneous coefficients on the housing market variables to be non-zero, but leaving their sign unrestricted, produces qualitatively the same results reported herein.

[17] To be precise, in the baseline specification in which the FED Funds rate is postulated not to react contemporaneously to housing market variables, $A_{0,j}^c = A_{0,j}$, so that $B_{0,j}^c = B_{0,j}$.

[18] So, to be absolutely clear, in *all* of these counterfactuals I *only* perturbate the parameters on the (lagged) price-rent ratio in the structural monetary policy rule, whereas the structural shocks—which, for each draw j, I had previously computed based on the original (i.e., non-perturbated) structural VAR as $\epsilon_t = A_{0,j}^{-1}[Y_t - B_{0,j} - B_{1,j}Y_{t-1} - ... - B_{p,j}Y_{t-p}]$—are left completely unchanged.

so that the entire machinery of structural VARs can still be applied—in order to allow them to have a non-negligible *cumulative* impact on real house prices, they must be allowed to operate for a sufficiently long period of time. This means that, for example, starting the counterfactuals (say) in 2002 or 2003, when the 'inflating phase' of the bubble was already in full swing, simply does not work,[19] because by then the winds blowing up the bubble were already so strong that only a comparatively large, and therefore *immodest* policy intervention might have reigned the disequilibrium in (and so, since it is immodest, it is not clear what to make of the entire experiment). Once again, it is important to stress the contrast between the approach explored herein, and either the one adopted by the FED in the 1920s, or that implicitly threatened by Alan Greenspan in his 'irrational exuberance' speech. Rather than ignoring the bubble for years (or even positively inflating it with a lax monetary policy), and then aggressively turning against it with interest rate hikes, the approach I explore herein is simply based on the notion of 'gently pushing the bubble down' every time it starts inflating. However, precisely because of the 'gentle nature' of the intervention, the only way for it to have an impact is to allow it to work for a sufficiently long period of time.

4.3 The impact of the counterfactuals on macroeconomic variables

Figures 4-11 report results from alternative counterfactual simulations, corresponding to different values of K, based on the baseline specification with M_2, and without ruling out the price puzzle. Figures A.7-A.14 in the online appendix report results based on the model with M_2 and ruling out the price puzzle.[20] Overall, results are robust to ruling out, or not ruling out the price puzzle, and for reasons of space in what follows I will therefore uniquely discuss the baseline set of results.

Figures 4 and 5 show, for the FED Funds rate, the unemployment rate, and real house prices, results from counterfactual simulations based on progressively more aggressive policy interventions, with K ranging from 0.005 to 0.002, whereas Figures 6-11 show results for the other variables for K equal to either 0.01, 0.015, or 0.02 (for manifestly trending variables—that is: real GDP, the PCE deflator, M_2, loans to real estate, and commodity prices—I report results for the annual rates of growth, rather than for the log-levels). As the policy intervention becomes more and more aggressive, the posterior distribution of the counterfactual path for the FED Funds rate moves higher and higher compared to the actual historical path. Up until the end of 2003, however, the difference between the counterfactual and actual paths remains (based on median estimates) quite small, being uniformly below 93 basis points even for K

[19] This evidence is available upon request.

[20] On the other hand, since, as previously discussed, I regard the IRFs produced by models featuring non-borrowed reserves as less plausible than those generated by models including M_2, I am not reporting results from counterfactual simulations based on models including non-borrowed reserves.

= 0.02, and even smaller than that based on smaller values of K. Since the early 2004, when the bubble truly started inflating in a significant way, the counterfactual FED Funds rate starts increasing rapidly, but once again, the difference between the counterfactual and actual paths is not enormous, peaking (based on median estimates) at 90, 158, 212, and 256 basis points, respectively, for the different values of K. The key issue, however, is not the *actual size* of the counterfactual increase in the FED Funds rate, but rather whether the policy interventions can be regarded as 'modest' in the sense of Leeper and Zha (2003), which I will explore in Section 5. For all interventions, the peak in the counterfactual FED Funds rate is reached well before the outbreak of the crisis in the Summer of 2007, reflecting the fact that, by then, the bubble had already started somehow deflating.

The corresponding results for real house prices and the unemployment rate shown in Figure 5 bring home two main points:

first, with a sufficiently aggressive policy intervention (in particular, by setting K to either 0.015 or 0.02), by the Summer of 2007 the housing bubble could have been essentially eliminated. In particular, as of July 2007, real house prices would have been (based on median estimates), 6.1, 10.6, 14.0, and 16.8 per cent lower than their actual, historical value, and they would have been roughly in line with the value they reached in the aftermath of the collapse of Lehman Brothers (which in the figure is marked by the second vertical blue line). The key point here is not to pick a specific estimate for equilibrium house prices in (say) July 2007, and then to find the policy intervention which is going to bring counterfactual house prices there. Rather, it is to show that progressively more aggressive interventions deflate house prices more and more, which implies that, irrespective of the specific belief one may hold for the equilibrium value of real house prices in the months immediately before the outbreak of the financial crisis, it is possible to find a perturbation which is going to bring counterfactual house prices there (then, the fact that such an intervention is modest is another matter).

Second, in contrast with the position often expressed by the Federal Reserve,[21] these policy interventions would *not* have been associated with a significant negative impact on real activity. In particular, based on median estimates, in July 2007 the unemployment rate would have been just 33, 57, 78, and 95 basis points higher than its actual, historical value.

An obvious question, at this point, is whether it would have made sense to endure a 78 basis points increase in the unemployment rate (with K = 0.015) in order to deflate real house prices by 14.0 per cent (which is in line with the extent of overvaluation of U.S. real house prices at the top of the bubble estimated by Benati (2015)). With the obvious benefit of hindsight, the answer is (at least, in my own

[21] See e.g. Dokko *et al.* (2011). As previously discussed, Dokko *et al.*'s argument crucially hinges on their position that *'[...] monetary policy actions affect house prices only a bit more forcefully than they affect GDP or unemployment [...]'*, which, as I showed in Section 3.1, is not supported by my empirical evidence.

view) a clear Yes: given the disastrous consequences wreaked by the unravelling of the housing bubble, a policy which would have (*i*) drastically limited its building up, and (*ii*) essentially eliminated it by the Summer of 2007, when the crisis struck, might well have prevented the worst consequences of the Great Recession. On the other hand, it ought to be stressed that this paper's goal is not to speculate on what might have happened during the period following the end of the counterfactual simulations, but rather to show that *via* a specific policy intervention the FED might have been able to first limit, and then eliminate the bubble.

Turning to the impact on other variables, it is uniformly quite subdued for PCE deflator inflation, loans to real estate, commodity prices, and housing starts, whereas it is non-negligible for hours in construction, which, at the end of the counterfactual simulation, turn out to be lower than the actual path by between 3.9 and 6.3 per cent. As for M_2, the impact is quite small up until early 2004, but it becomes non-negligible since then, with the annual rate being systematically lower than the actual, historical path by between one and two percentage points. Finally, in line with the previously discussed evidence for the unemployment rate, the impact on GDP is overall modest: based on $K = 0.02$, for example, the difference between counterfactual and actual annual GDP growth oscillates (based on median estimates) between zero and about minus 25 basis points up until early 2004, and although it rapidly decreases since then, starting from early 2006 it oscillates between minus 85 and minus 120 basis points.

The key issue, now, is whether the just-discussed policy interventions might be regarded as 'modest', and therefore such as not to trigger revisions in expectations on the part of economic agents which would likely invalidate the entire experiment. Before turning to this, however, I briefly discuss results from three other possible perturbations of the FED's structural monetary rule.

4.4 Results from other perturbations of the structural monetary policy rule

What about other perturbations of the structural monetary rule? Would have been possible to prevent the housing bubble by having the FED Funds rate reacting (e.g.) to loans to real estate? In this section I briefly discuss results from three alternative policy interventions, in which the parameters of the FED's structural monetary policy rule are perturbated in such a way that the FED Funds rate reacts in a marginally more aggressive way to either loans to real estate, GDP, or the PCE deflator.[22] Unsurprisingly, reacting to either GDP or the PCE deflator does not prevent the bubble from inflating. In particular, the fact that the aggressive pursuit of price

[22] Details of the experiments are exactly the same as before, with the only difference that, instead of reacting to the price-rent ratio, the FED Funds rate is now reacting to either of the three alterrnative variables. For reasons of space, results are not reported even in the online appendix, but they are all available upon request.

stability is *not incompatible* at all with the building up of asset prices' bubbles provides a straightforward illustration of arguments long made at the *Bank for International Settlements*,[23] and succintly expressed by William White in his well-known quip that 'price stability is not enough'. As for reacting to loans to real estate, although it would have allowed to (partly) prevent the bubble, it would have done so in a less efficient way than by reacting to the price-rent ratio. In particular, the cost in terms of both increases in the unemployment rate, and decreases in GDP, would have been higher. The straightforward explanation for this is that the link between the expansion of credit to real estate and the inflating of the housing bubble is not perfect, so that, by reacting to loans to real estate, the FED is in fact reacting to an 'imperfect intermediate target'. As a result, greater increases in the FED Funds rate are needed, resulting in a larger impact on real economic activity.

5 Are These Perturbations 'Modest Policy Interventions'?

Are the previously discussed perturbations 'modest policy interventions' in the sense of Leeper and Zha (2003)? As I now show, this is indeed the case. Before delving into the evidence, however, I start by discussing an important conceptual issue pertaining to the assessment of the modesty of a policy intervention.

5.1 A conceptual issue pertaining to the assessment of the modesty of a policy intervention

Leeper and Zha's (2003) proposal for assessing the 'modesty' of a specific policy intervention over the horizon $\tau+h$, $h = 1, 2, 3, ..., H$, is based on the notion of performing such an assessment based on the (im)plausibility of the resulting counterfactual path(s) for the FED Funds rate (and maybe for the other variables in the VAR) from the perspective of a forecast based on information at time τ.[24]

An important issue within Leeper and Zha's (2003) approach is the choice of which shock(s) the time-τ forecast(s) should be conditioned upon. Whereas Leeper and Zha (2003) originally conditioned the forecasts uniquely on monetary policy

[23] See in particular Borio and White (2003).

[24] Focusing, for the sake of simplicity, on the FED Funds rate, the intuition is that if its counterfactual path deviates significantly from its median forecast conditional on information at τ, this can be taken as evidence that something in the FED's structural monetary policy rule has changed. This will induce rational economic agents to revise their expectations, which in turn, working through the cross-equation restrictions encoded in the DSGE model underlying the structural VAR, will change the structure of the VAR itself, thus invalidating the results of the entire counterfactual experiment. The 'modesty' of a policy intervention—i.e., its congruency with the monetary authority's previous historical behaviour—is therefore a necessary condition in order to be able to reliably assess the intervention's impact within a structural VAR framework.

shocks, Adolfson, Laséen, Lindé, and Villani (2005) argued that, since, in general, the economy is hit by a multitude of structural disturbances, and all available evidence suggests that the importance of monetary shocks is comparatively modest, a more sensible choice would be to condition the forecast on all of the structural disturbances. So let me briefly discuss why, as matter of simple logic, I regard Adolfson *et al.*'s (2005) position correct, which is why, in what follows, I will adopt their approach. In a nutshell, the key point is that conditioning the forecast only upon monetary shocks systematically biases the assessment towards the finding of non-modesty of the policy intervention.

5.1.1 Problems with conditioning the forecasts uniquely on monetary policy shocks

In order to focus ideas, let's start by considering the extreme case in which there are *no monetary policy shocks* (i.e., their variance is equal to zero), and let's also assume that neither the parameters of the structural monetary policy rule, nor any of the other parameters in the VAR, experience any change whatsoever. Under these circumstances, for either of the variables in the VAR the 'distribution' of the forecast at horizon $\tau+h$, $h = 1, 2, 3, ..., H$, conditional on information at time τ, and *only conditional on monetary shocks*, will be degenerate, as for each horizon $\tau+h$ it will simply be equal to a scalar. Under the plausible assumption that the variance of at least one of the non-monetary shocks is different from zero—so that there is indeed a stochastic element in the system—this logically implies that the probability that the actual values taken by the variables in the VAR at horizon $\tau+h$ will be equal to the forecasted values is zero, so that, in general, the variables' actual paths will deviate from the paths predicted conditional on information at time τ. If, under these circumstances, we applied 'mechanically' Leeper and Zha's approach, such deviations would induce us to erroneously infer that there has been an immodest policy intervention even if, by assumption, we ruled out any change in the parameters of the structural monetary policy rule. Further, this logically implies that, under these circumstances, *any* policy intervention will be regarded as immodest, irrespective of its magnitude.

Although the assumption that the variance of monetary policy shocks is equal to zero is extreme, in practice, as we have previoulsy discussed, monetary policy shocks explain very little of the forecast error variance of any variable, which implies that for all variables the bulk of their fluctuations is driven by other shocks. In turn, this implies that assessing the modesty of a policy intervention based on the (im)plausibility of the resulting path for the FED Funds rate (and maybe of other variables), where such (im)plausibility is assessed from the perspective of a forecast computed only conditional on monetary policy shocks

(i) is biased towards detecting immodesty, with

(ii) the bias being greater the smaller the importance of monetary shocks in driving the variables in the VAR, compared to other shocks.

Because of this, in what follows I will assess the immodesty of the policy interventions associated with the perturbation of the parameters of the structural monetary rule based on forecasts computed conditional on all shocks.

I now turn to discussing the computation of the conditional forecasts for the FED Funds rate and the other variables in the VAR.

5.2 Issues pertaining to the computation of the conditional forecasts

I compute forecasts over the period January 1995-July 2007, conditional on information up to December 1994, by taking as initial conditions the data up to December 1994, and then stochastically simulating the VAR into the future for each single draw from the posterior. In this way, I build up, for each single variable, the posterior distribution of the conditional forecasts. I now turn to discussing three specific issues pertaining to the computation of the projections.

5.2.1 Taking into account of the zero lower bound on the FED Funds rate

In computing the forecasts, I take into account of the zero lower bound on the FED Funds rate by simply rescaling (if needed) the randomly drawn monetary policy shocks for each horizon $\tau+h$, $h = 1, 2, 3, ..., H$, so that the resulting simulated path for the FED Funds rate never goes below zero.[25]

5.2.2 Taking into account of the constraints on the unemployment rate

By the same token, I take into account of the fact the unemployment rate cannot be either negative, or greater than one, by simply rejecting all simulated paths for which either of the two constraints is violated.[26]

[25] Specifically, for each draw j from the posterior, starting from time τ, and for each $t = \tau$, $\tau+1$, $\tau+2$, $\tau+3$, ..., $\tau+H$-1, I compute a 'candidate time-($t+1$) realization' for the variables in the VAR—let's call it, $Y_{t+1}^{j,c}$—based on a random draw of a time-($t+1$) vector of i.i.d. normal (0, 1) shocks. Let the resulting candidate realization of the FED Funds rate be $r_{t+1}^{j,c}$. If $r_{t+1}^{j,c} \geq 0$ I keep it. Otherwise, I rescale the randomly drawn time-($t+1$) monetary policy shock in such a way that $r_{t+1}^{j,c} = 0$. Then, I move to the next period. This approach was (and maybe still is) used at central banks in order to compute forecasts conditional on a constant path for the monetary policy rate (so-called 'constant interest rate projections').

[26] This was the approach used by Cogley and Sargent (2002) for imposing the zero lower bound on the interest rate.

5.2.3 Why computing forecasts based on the VAR estimated over the entire sample period

In what follows I report results based on conditional forecasts which have been computed based on the VAR estimated for the full sample period from January 1963 to July 2007 (i.e., the VAR I have been working all along). The reason for this is simply that results from the corresponding exercise in which the conditional forecasts have been computed based on the VAR estimated with data up to December 1994 are even stronger than those I report in Figures 12-15, i.e., they suggest in an even stronger way that the perturbations of the FED's structural monetary rule can indeed be regarded as 'modest policy interventions' (these results are not reported here for reasons of space, but they are available upon request). The reason for this is that the shorter sample period necessarily produces less precise estimates (i.e., more dispersed posterior distributions for all of the VAR's parameters), which logically results in more 'spread out' conditional forecasts. In turn, this inevitably produces, *ceteris paribus*, smaller values for Leeper and Zha's 'modesty statistics'.

Summing up, these results clearly suggest that the previously discussed perturbations of the FED's structural monetary policy rule should indeed be regarded as 'modest policy interventions'. This, in turn, suggests that a modest intervention in which the Federal Funds rate had reacted, weakly but systematically, to the ratio between house prices and rents would have prevented the building up of the housing bubble which pre-dated the Great Recession, at a small cost in terms of real activity.

5.3 Evidence

Figure 12 shows, for the four alternative values of K considered herein, the median of the posterior distribution of Leeper and Zha's 'modesty statistic' for the FED Fund rate, together with the 5th and 95th percentiles, whereas Figures 13-15 show the corresponding results for the other variables in the VAR, for K equal to 0.01, 0.015, and 0.02, respectively. The key result emerging from the figures is that in no way evidence does suggest that the previously discussed perturbations of the parameters of the FED's structural monetary rule may be regarded as immodest, and therefore such as to trigger revisions in expectations on the part of the public such as to change the very structure of the VAR, therefore invalidating the entire exercise. In particular, for all variables, both the 5th and the 95th percentiles of the posterior distributions of the modesty statistics are typically well inside the interval [-2; 2], with the single, limited exception of hours in construction, for which, for a few months at the very beginning of the sample, the posterior distribution fluctuates very close to -2. Further, for the FED Funds rate—but not for all of the other variables in the VAR—the same holds true even if the modesty statistics are computed based on forecasts uniquely conditioned on monetary policy shocks (this evidence is not reported for reasons of space, but it is available upon request).

6 Conclusions

In this paper I have shown that a 'modest policy intervention' in which the Federal Funds rate had reacted, weakly but systematically, to the ratio between house prices and rents would have prevented the building up of the housing bubble which pre-dated the Great Recession, at a small cost in terms of real activity. Monetary policy shocks, which I identify by combining zero and sign restrictions, cause strongly statistically significant decreases in real house prices, housing starts, hours worked in construction, and loans to the real estate sector, and a statistically significant temporary increase in the real rent.

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A The Data

Here follows a detailed description of the dataset.

A monthly seasonally adjusted series for the core personal consumption expenditure deflator ('PCEPILFE: Personal Consumption Expenditures Excluding Food and Energy, Chain-Type Price Index, Seasonally Adjusted, Monthly, Index 2009=100') is from the U.S. Department of Commerce: Bureau of Economic Analysis. A monthly seasonally unadjusted series for the Federal Funds rate ('FEDFUNDS: Effective Federal Funds Rate, Monthly, Not Seasonally Adjusted, Percent') is from the Board of Governors of the Federal Reserve System. A monthly seasonally unadjusted population series ('CNP16OV: Civilian Noninstitutional Population, Monthly, Not Seasonally Adjusted, Thousands of Persons') is from the U.S. Department of Labor: Bureau of Labor Statistics. A monthly seasonally adjusted housing starts series ('HOUST: Housing Starts: Total: New Privately Owned Housing Units Started, Seasonally Adjusted Annual Rate, Monthly') is from the U.S. Department of Commerce: Census Bureau. A monthly seasonally adjusted series for loans to real estate ('REALLN: Real Estate Loans, All Commercial Banks, Seasonally Adjusted, Monthly, Billions of Dollars') is from the Board of Governors of the Federal Reserve System. A monthly seasonally adjusted series for overall hours worked in the construction sector has been constructed as in Iacoviello and Neri (2010), that is, as the product of all employees in the construction sector and average hours worked in construction. In turn, the two monthly seasonally adjusted series for all employees in construction ('USCONS: All Employees: Construction, Seasonally Adjusted, Monthly, Thousands of Persons') and for average hours worked in construction ('CES2000000007: Average Weekly Hours of Production and Nonsupervisory Employees: Construction, Seasonally Adjusted, Monthly, Average Hours') are both from U.S. Department of Labor: Bureau of Labor Statistics. A monthly seasonally adjusted series for the unemployment rate ('UNRATE: Civilian Unemployment Rate, Seasonally Adjusted, Monthly, Percent') is from the U.S. Department of Labor: Bureau of Labor Statistics. A monthly seasonally adjusted series for interpolated real GDP is from Mark Watson's website. The series is the one which has been used in Stock and Watson (2012). A monthly seasonally unadjusted series for the commodity price index ('PPIACO: Producer Price Index: All Commodities, Producer Price Index, Not Seasonally Adjusted, Monthly, Index 1982=100') is from the U.S. Department of Labor: Bureau of Labor Statistics. A monthly seasonally adjusted series for M_2 ('M2SL: M2 Money Stock: H.6 Money Stock Measures, Seasonally Adjusted, Monthly, Billions of Dollars') is from the Board of Governors of the Federal Reserve System. A monthly seasonally adjusted series for non-borrowed reserves ('BOGNONBR: Non-Borrowed Reserves of Depository Institutions; Seasonally Adjusted; Monthly; Billions of Dollars') is from the Board of Governors of the Federal Reserve System. The series was discontinued in June 2013, but that is irrelevant for my purposes since, in order to prevent my results from being distorted by the financial crisis and the associated

Great Recession, I end the sample period in the month before the beginning of the crisis, July 2007. A monthly seasonally unadjusted series for the median sales price of new homes sold in the United States is from the website of the Manufacturing and Construction Division, Residential Construction Branch, of the U.S. Census Bureau (http://www.census.gov/construction/nrs/historical_data/historic_releases.html). The original seasonally unadjusted series has been seasonally adjusted *via* ARIMA X-12. As for the rent series, the ideal one to use would be the owner's equivalent rent component of the CPI ('CUSR0000SEHC: Consumer Price Index for All Urban Consumers: Owners' equivalent rent of residences, Seasonally Adjusted, Monthly, Index December 1982=100'). The problem with this series is that it is comparatively short, as it starts in January 1983, thus limiting the analysis to just 24 years and half. In the paper I have therefore used, as rent series, the shelter component of the CPI ('CUSR0000SAH1: Consumer Price Index for All Urban Consumers: Shelter, Consumer Price Index, Seasonally Adjusted, Monthly, Index 1982-84=100'), which starts in January 1953, and over the common sample period has been remarkably close to the owner's equivalent rent component (both series are from the U.S. Department of Labor: Bureau of Labor Statistics). Figure A.1 in the online appendix documents this, by showing the logarithms of the two series since 1983. As the figure clearly shows, for most of the sample period it is near-impossible to tell which of the two series is which, thus bringing home the point that the shelter component of the CPI provides an excellent proxy for the owner's equivalent rent component. In particular, since January 1983 the absolute value of the percentage deviation of the shelter component of the CPI from the owner's equivalent rent component has been equal, on average, to 0.47 per cent, with a maximum value equal to 1.33 per cent. This—together with the fact that, as I discuss in Benati (2015), in a few cases the results obtained based on the owner's equivalent rent component are manifestly implausible (most likely due to the short sample period)—suggest that using the shelter component of the CPI is most likely the best choice.

The overall sample period is January 1963-July 2007.

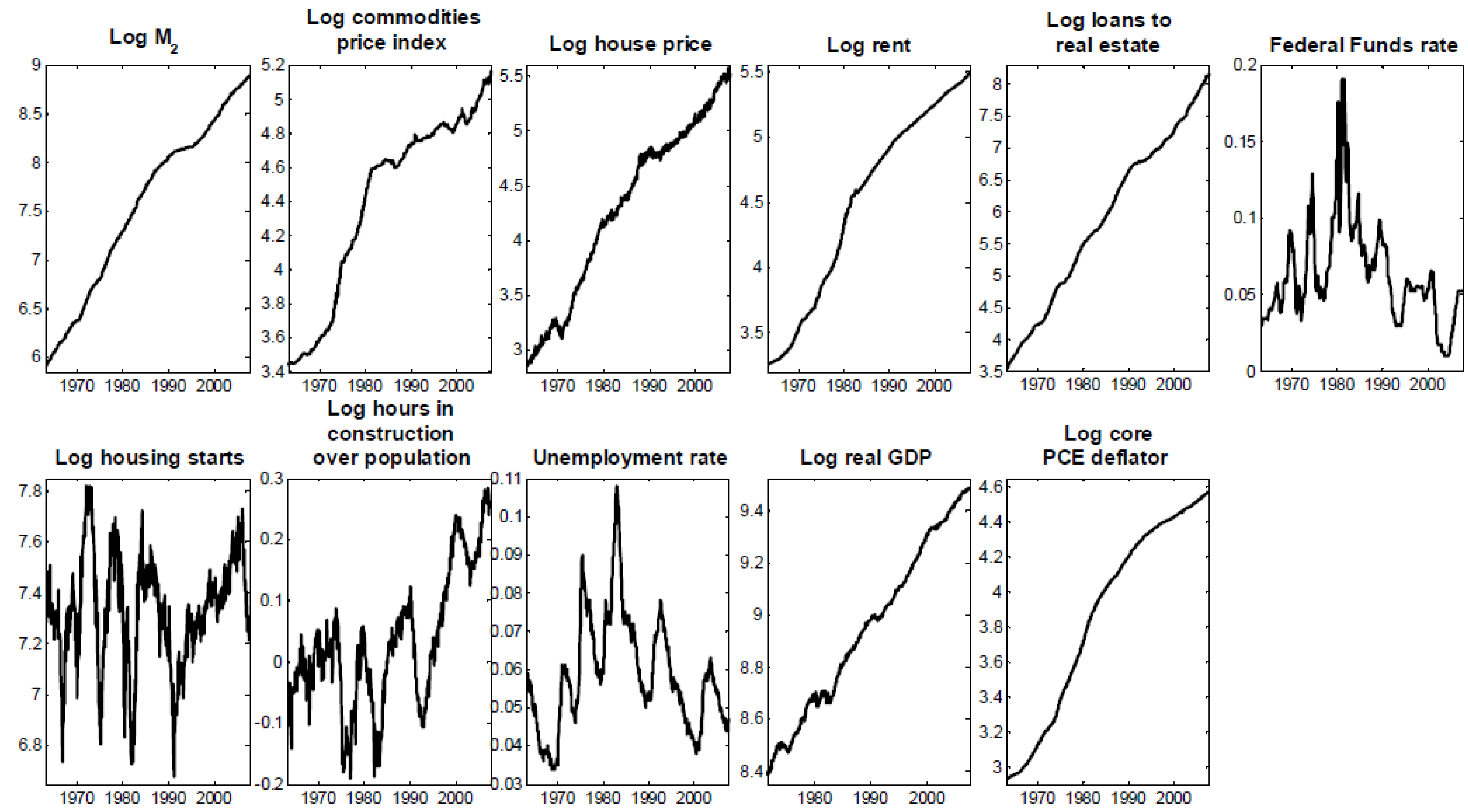

Figure 1 The raw data

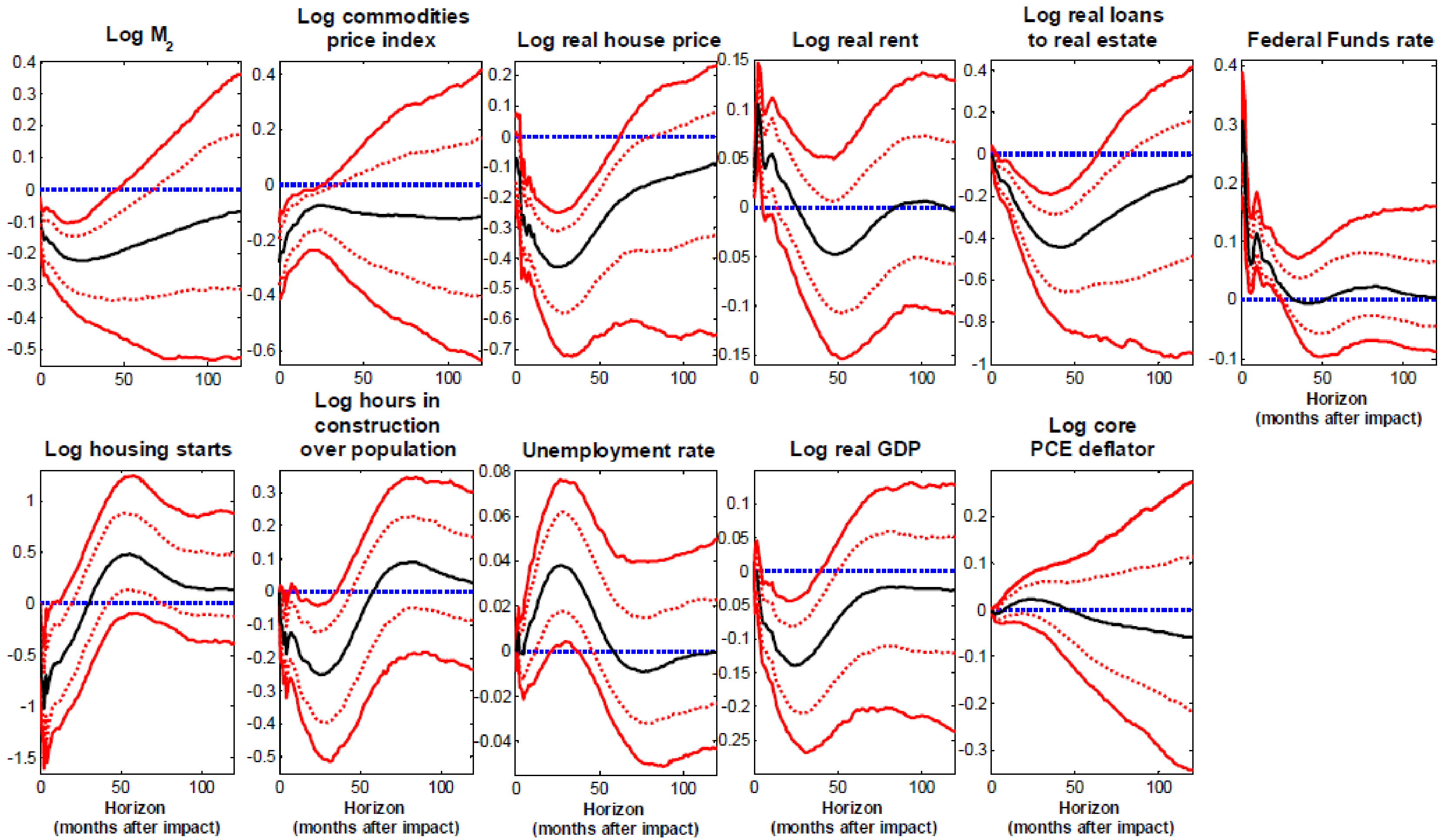

Figure 2 Impulse-response functions to a monetary policy shock (median, and 16-84 and 5-95 percentiles)

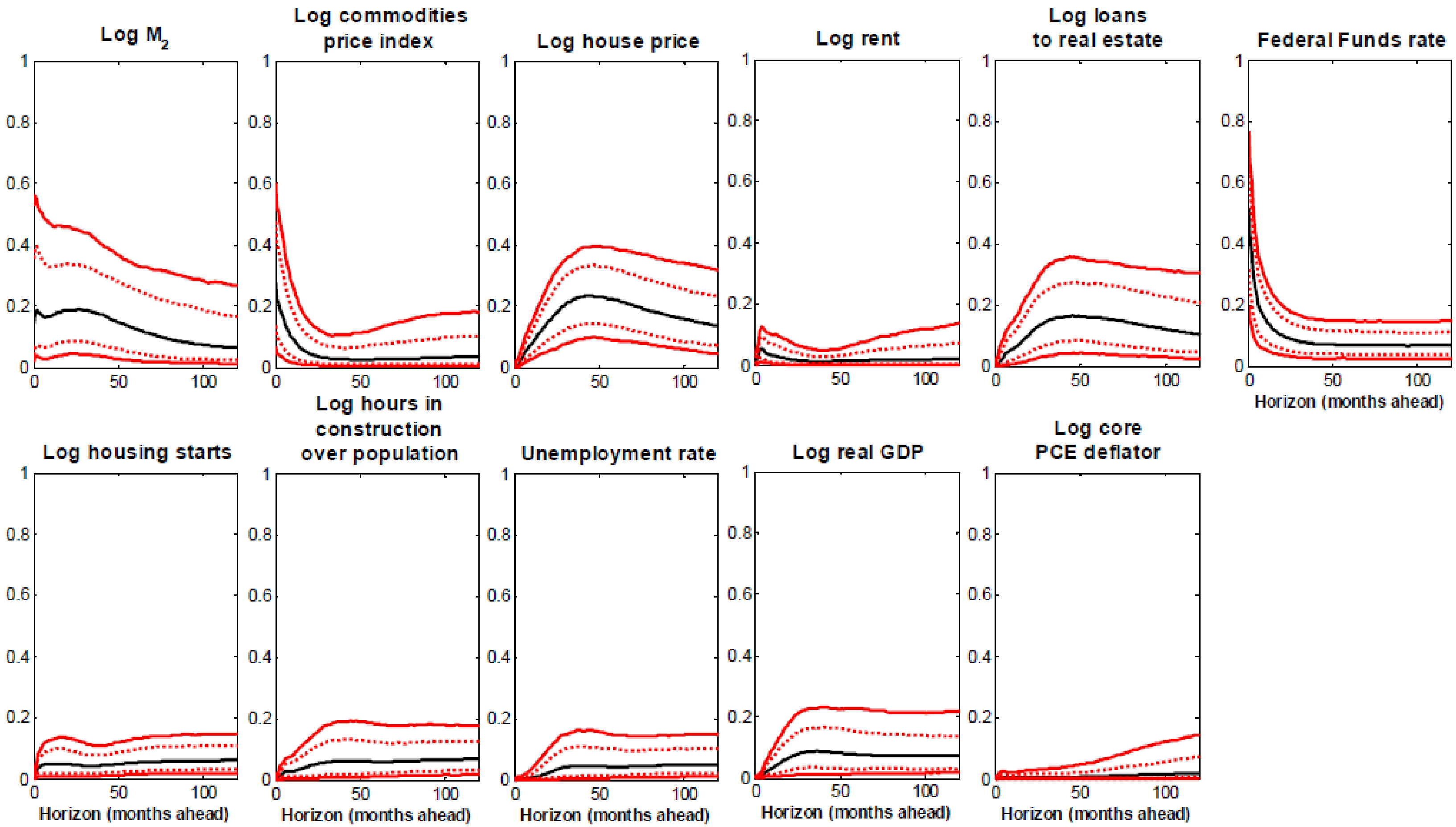

Figure 3 Fractions of forecast error variance explained by monetary policy shocks (median, and 16-84 and 5-95 percentiles)

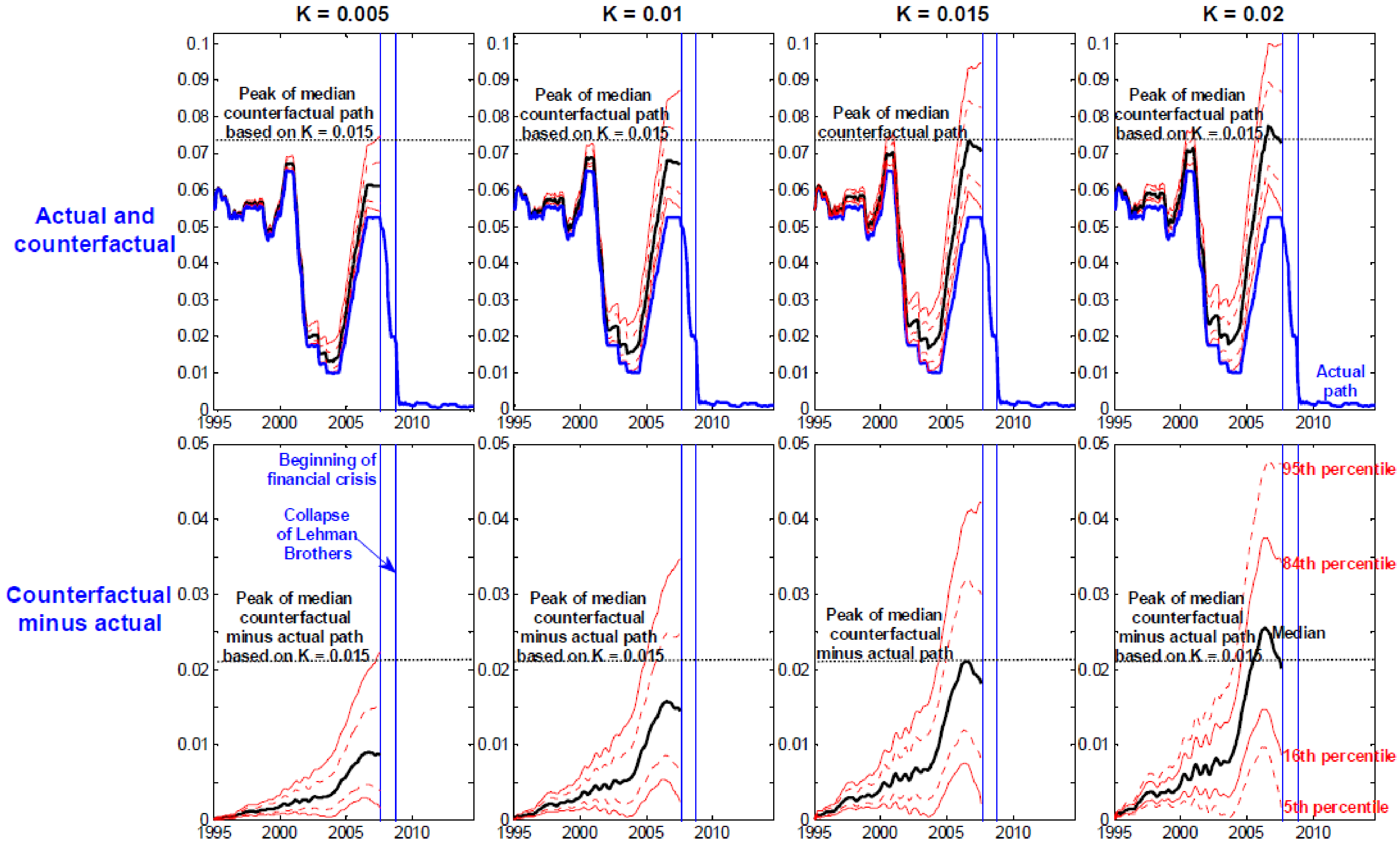

Figure 4 Actual and counterfactual paths for the Federal Funds rate based on alternative policy interventions (median, and 16-84 and 5-95 percentiles)

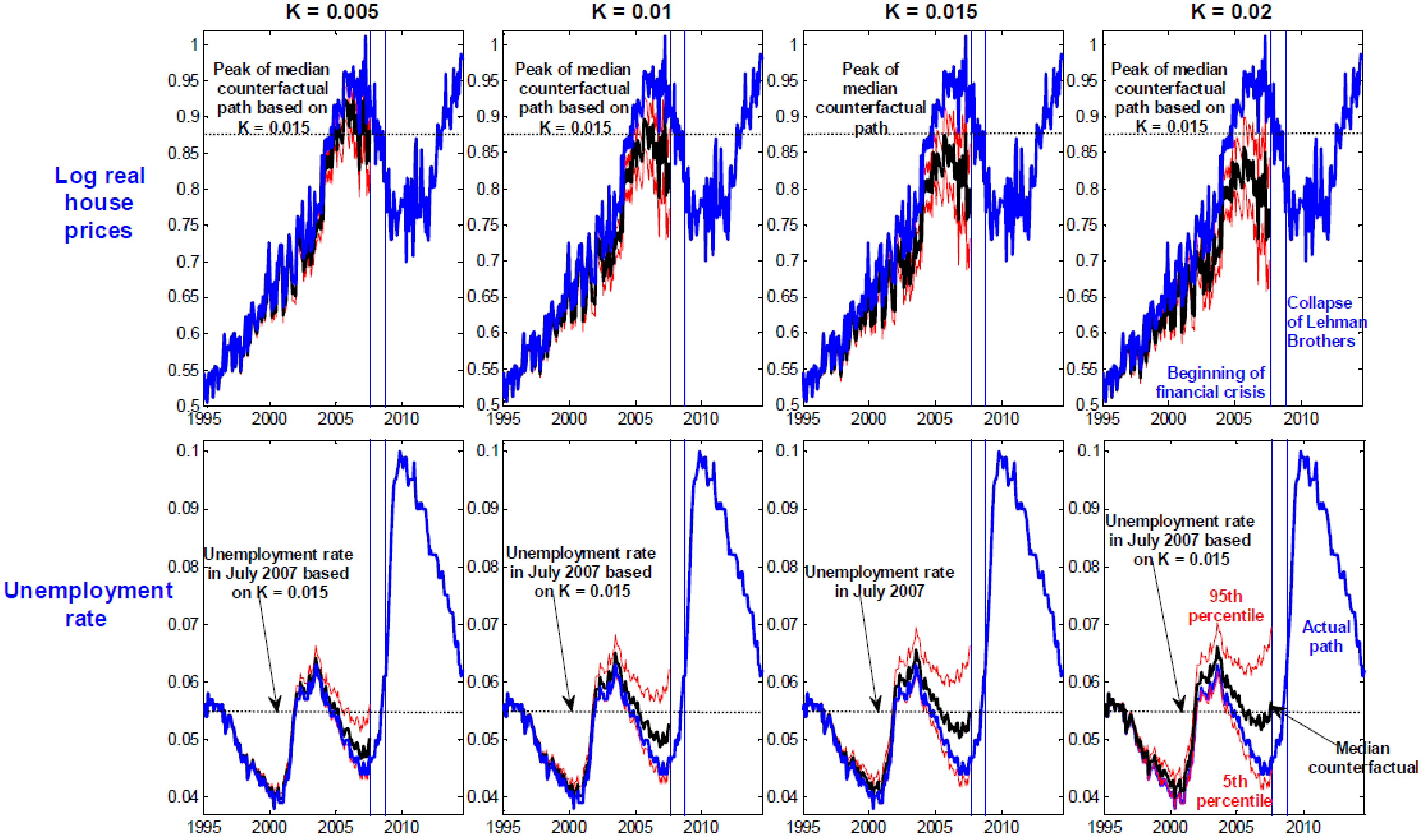

Figure 5 Actual and counterfactual paths for log real house prices and the unemployment rate based on alternative policy interventions (median, and 5-95 percentiles)

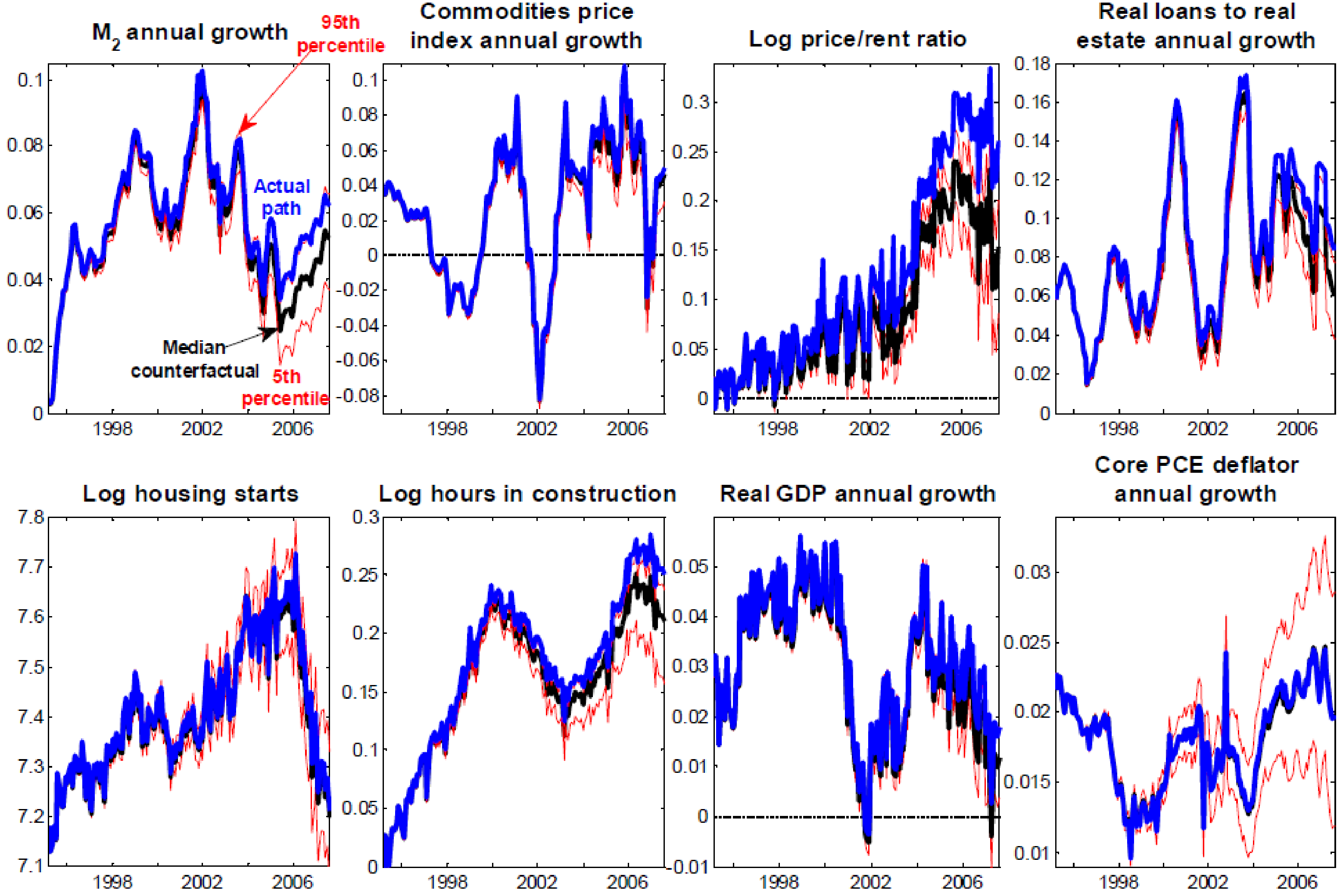

Figure 6 Actual and counterfactual paths for the other variables in the VAR based on a policy intervention with K = 0.01 (median, and 5-95 percentiles)

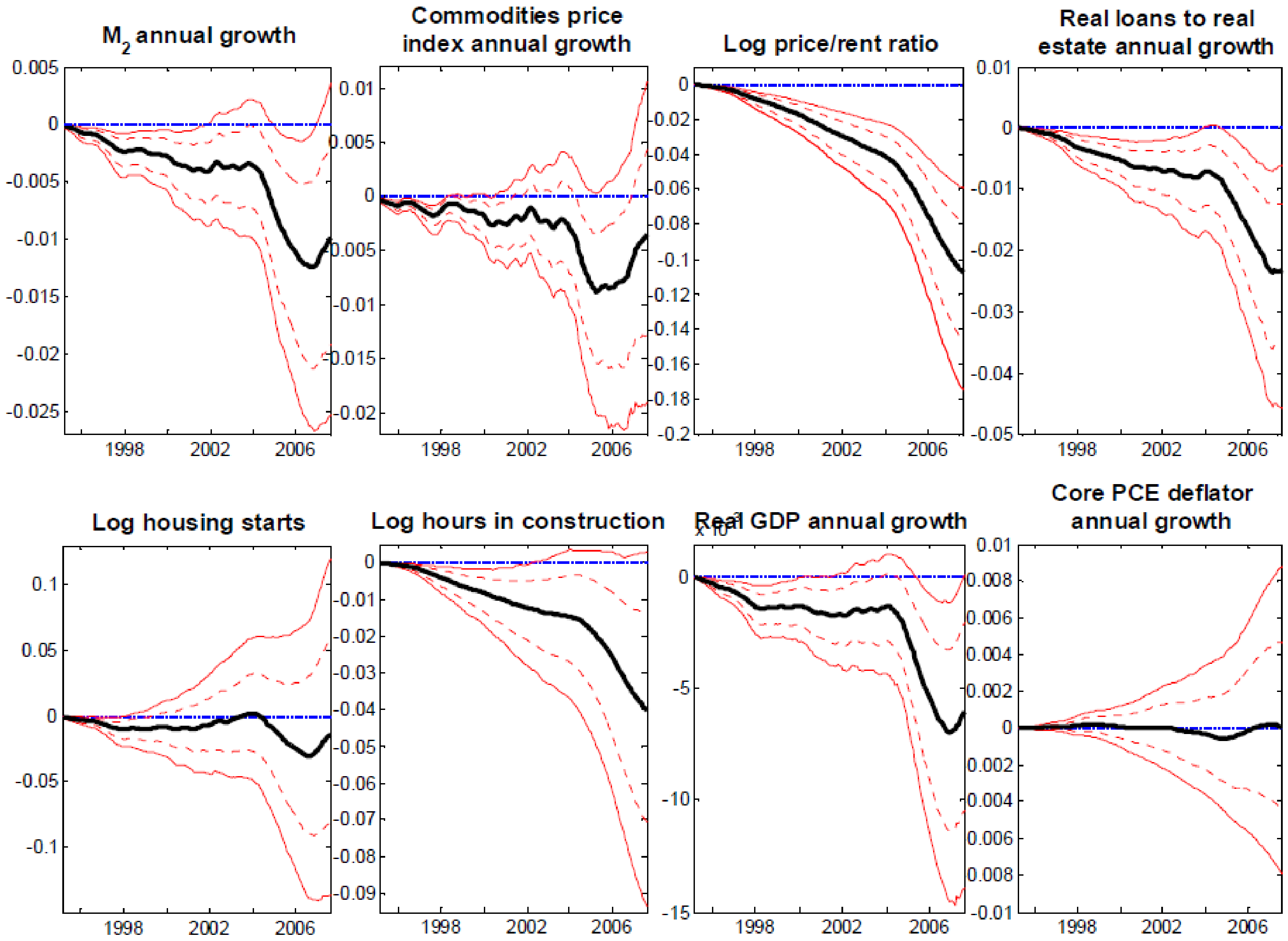

Figure 7 Difference between counterfactual and actual paths for the other variables in the VAR based on a policy intervention with K = 0.01 (median, and 16-84 and 5-95 percentiles)

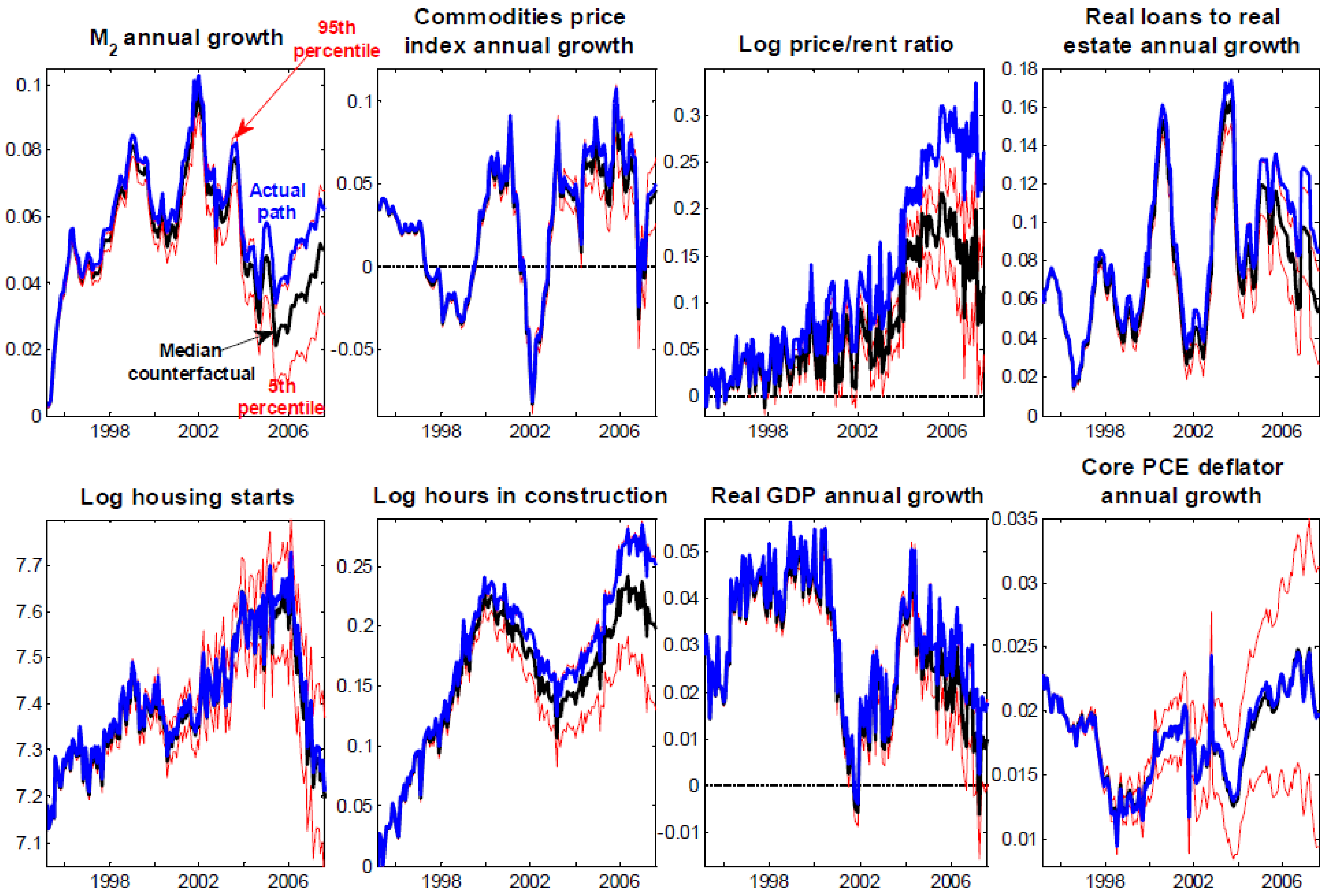

Figure 8 Actual and counterfactual paths for the other variables in the VAR based on a policy intervention with K = 0.015 (median, and 5-95 percentiles)

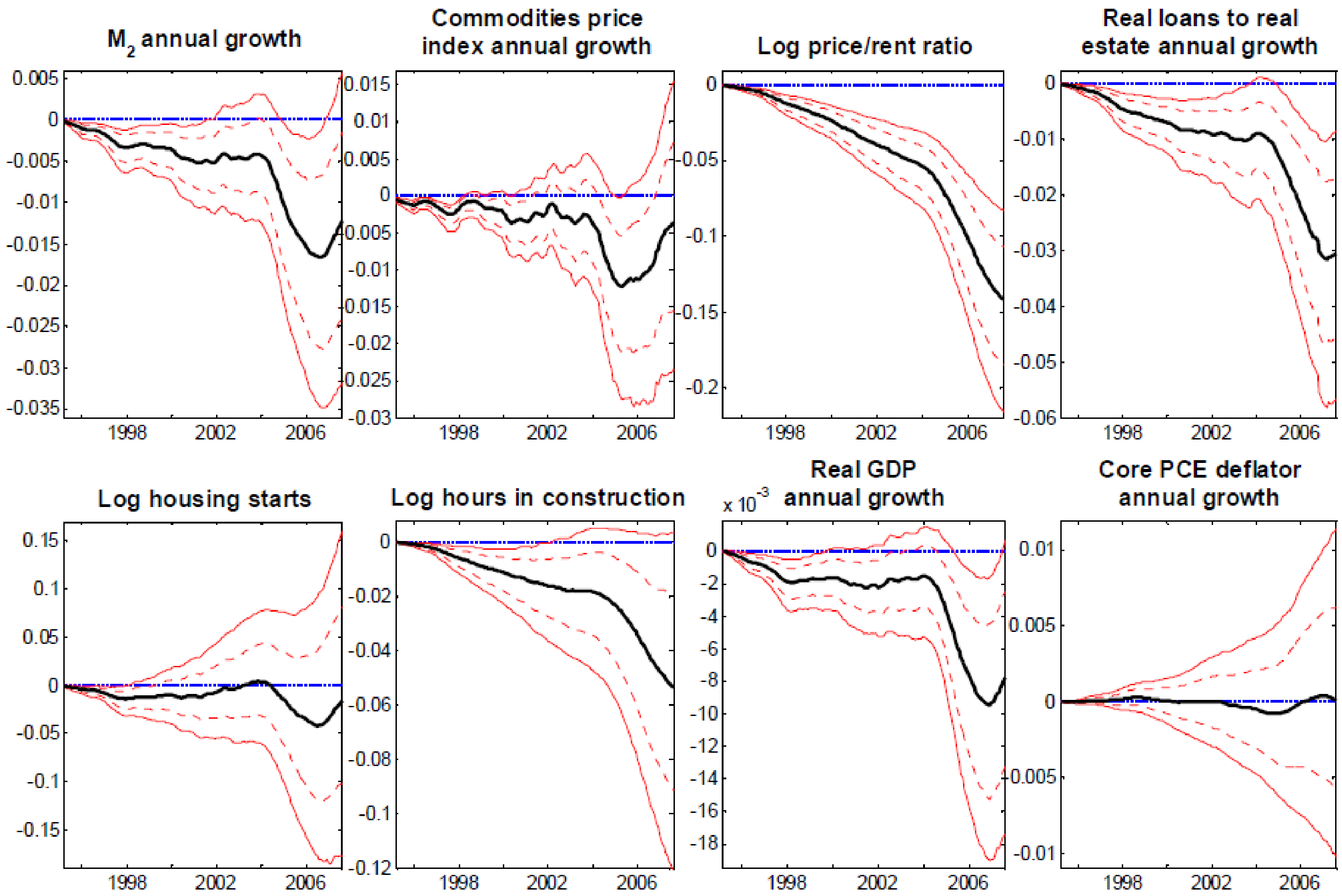

Figure 9 Difference between counterfactual and actual paths for the other variables in the VAR based on a policy intervention with K = 0.015 (median, and 16-84 and 5-95 percentiles)

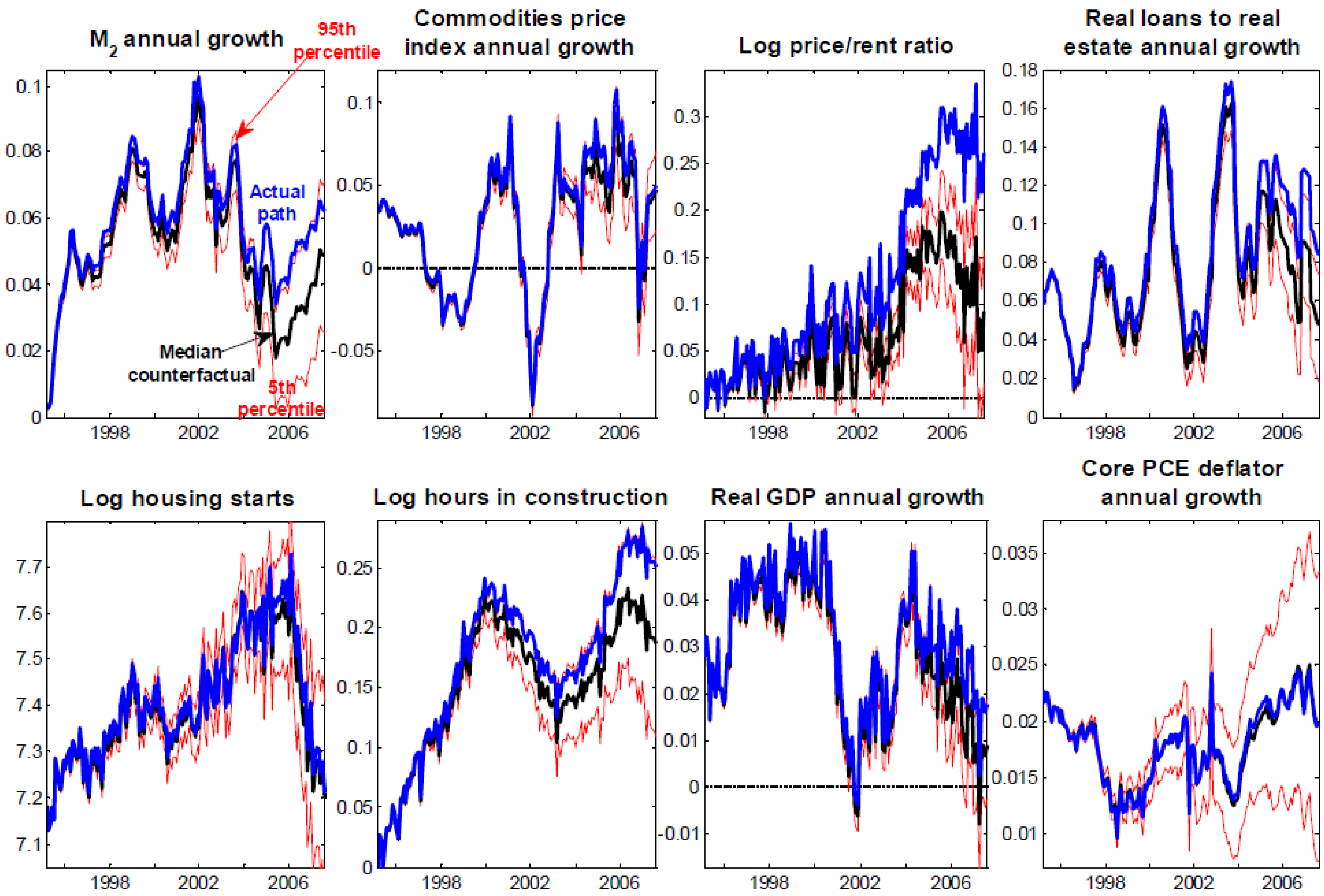

Figure 10 Actual and counterfactual paths for the other variables in the VAR based on a policy intervention with K = 0.02 (median, and 5-95 percentiles)

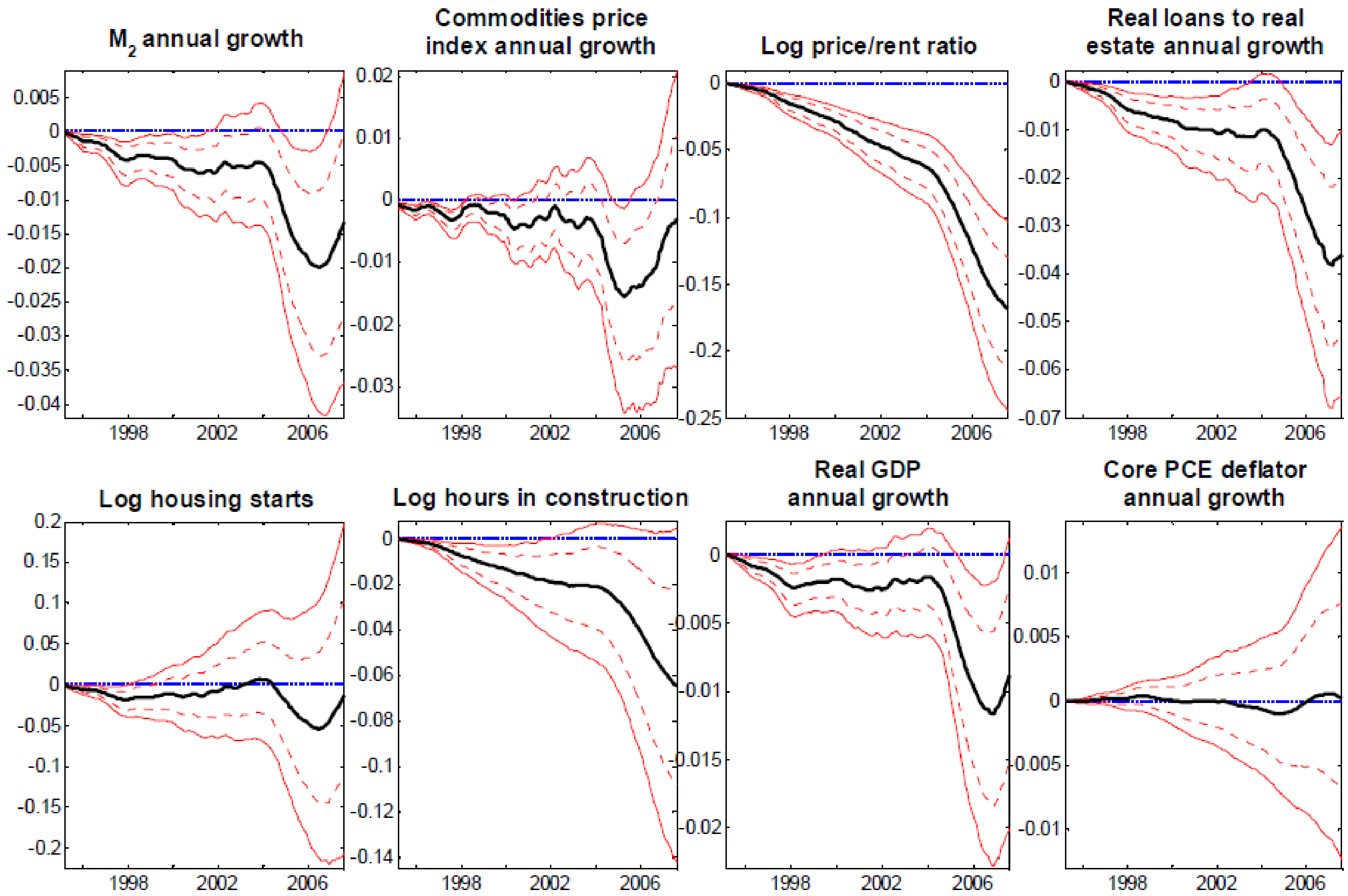

Figure 11 Difference between counterfactual and actual paths for the other variables in the VAR based on a policy intervention with K = 0.02 (median, and 16-84 and 5-95 percentiles)

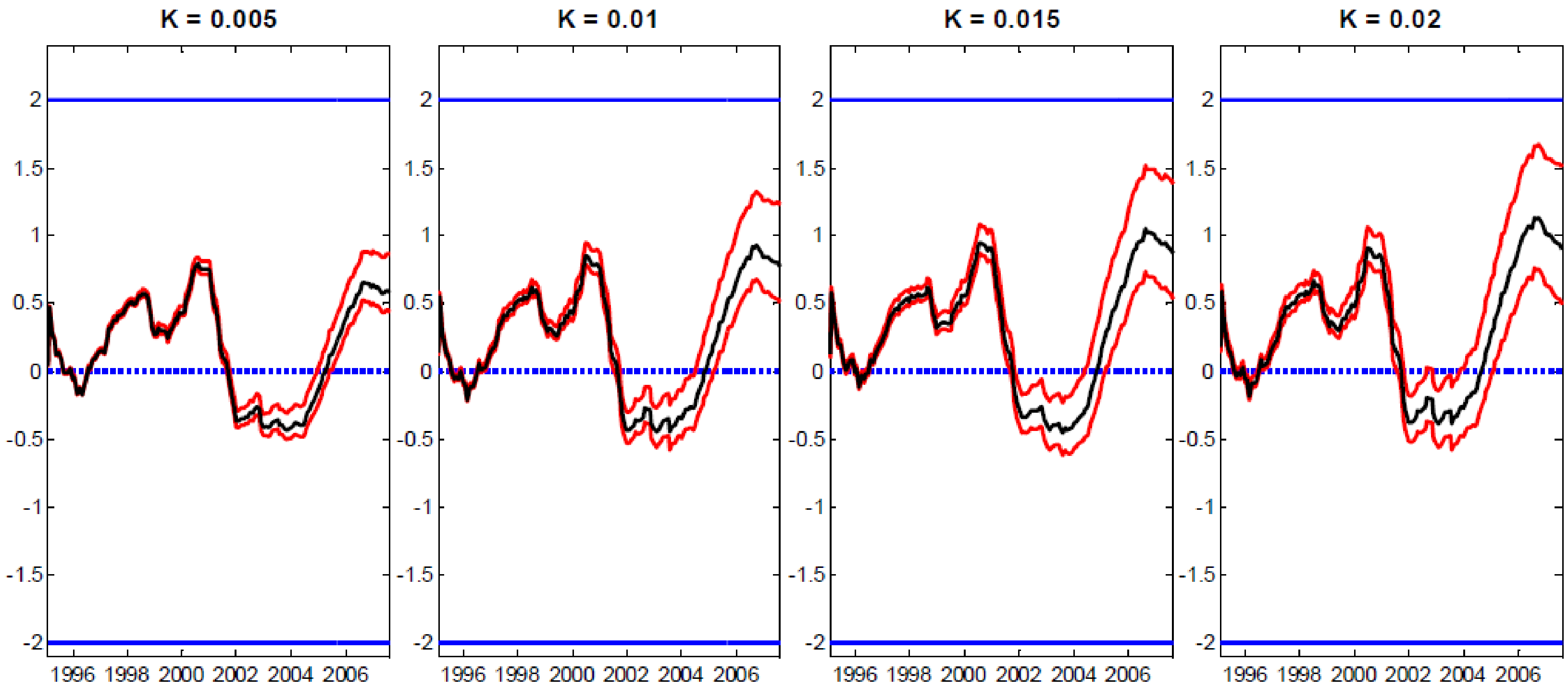

Figure 12 Leeper and Zha's modesty statistic for the Federal Funds rate (medians, and 5-95 percentiles)

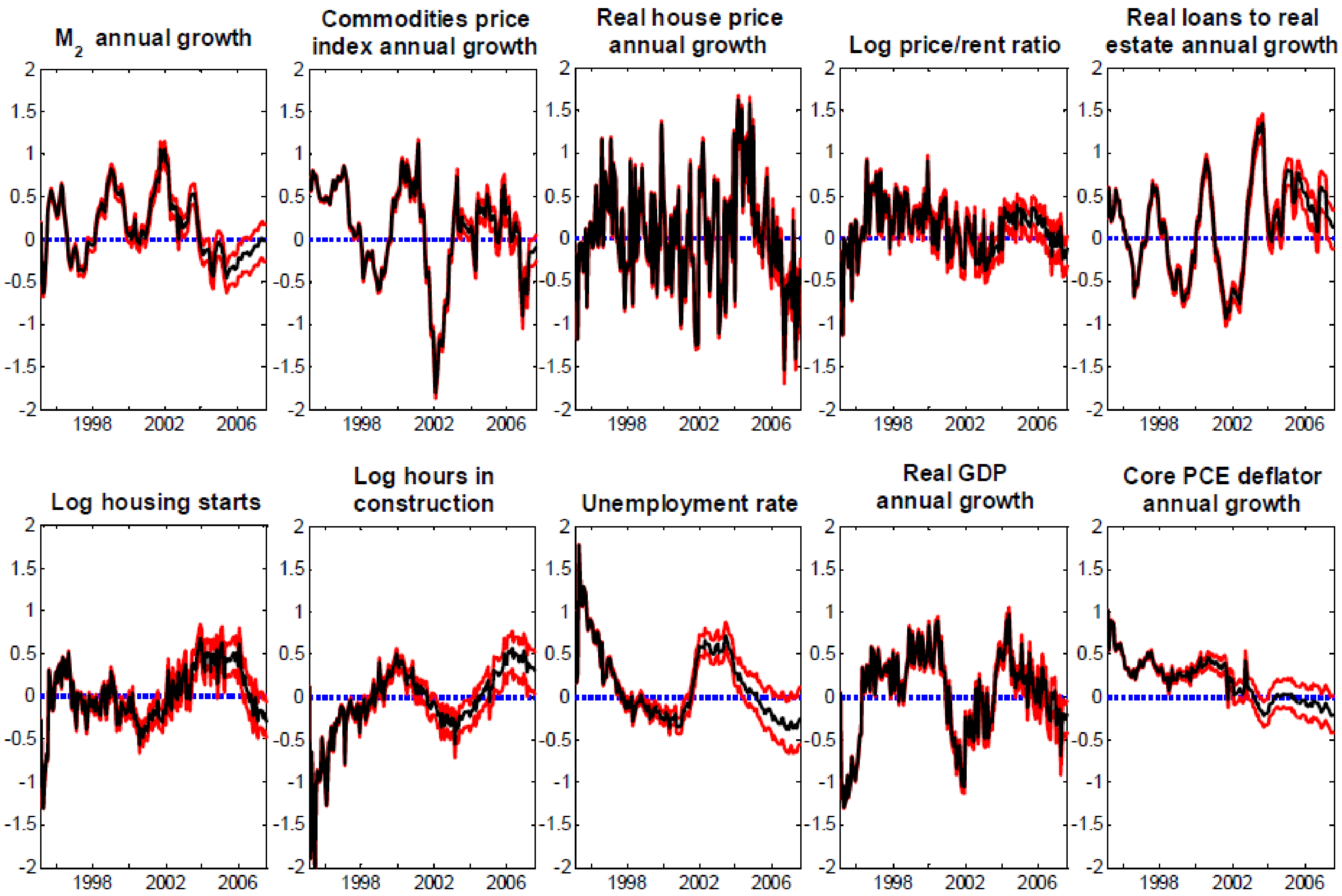

Figure 13 Leeper and Zha's modesty statistic for variables other than the Federal Funds rate, for $K = 0.01$ (medians, and 5-95 percentiles)

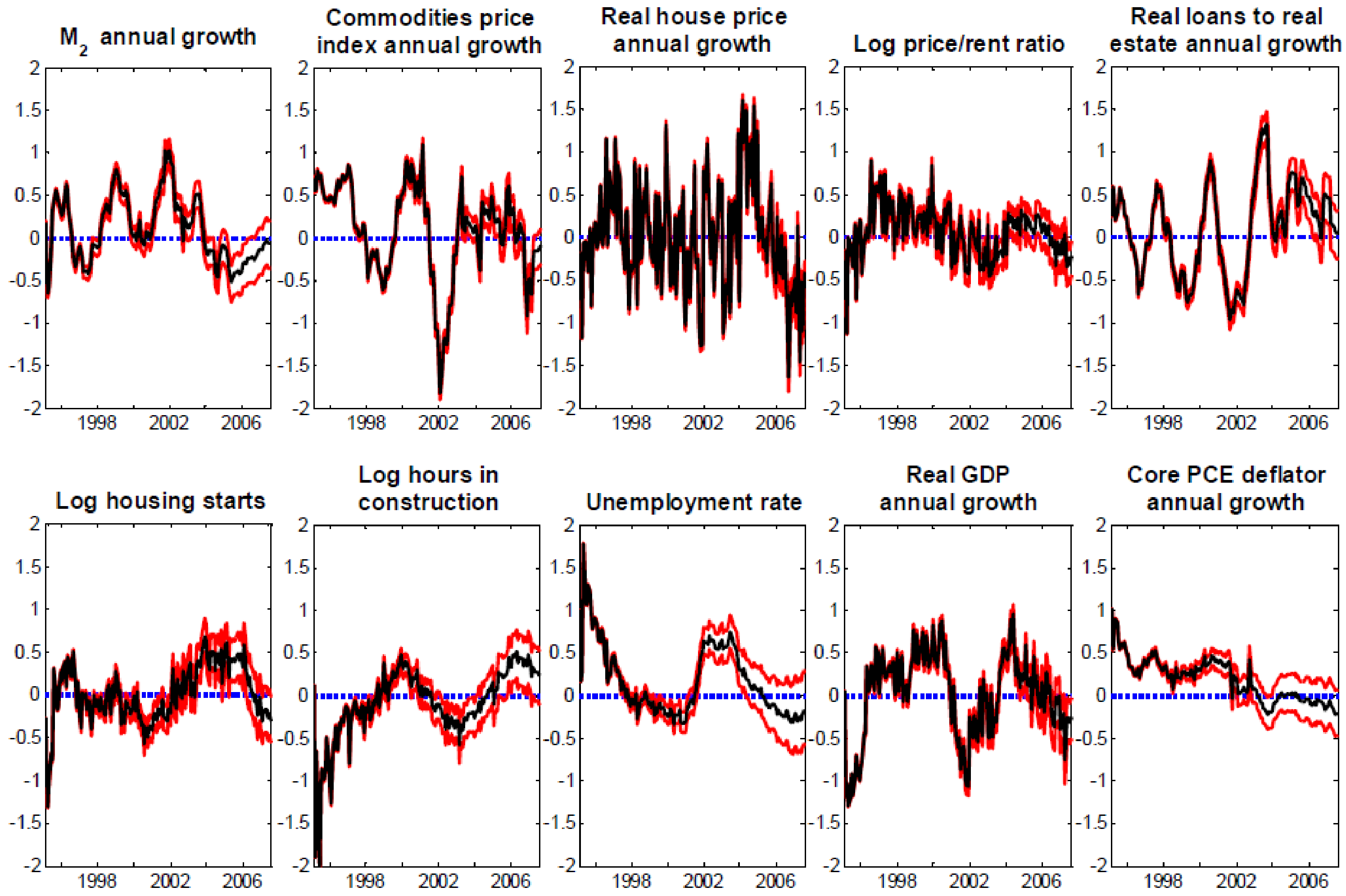

Figure 14 Leeper and Zha's modesty statistic for variables other than the Federal Funds rate, for $K = 0.015$ (medians, and 5-95 percentiles)

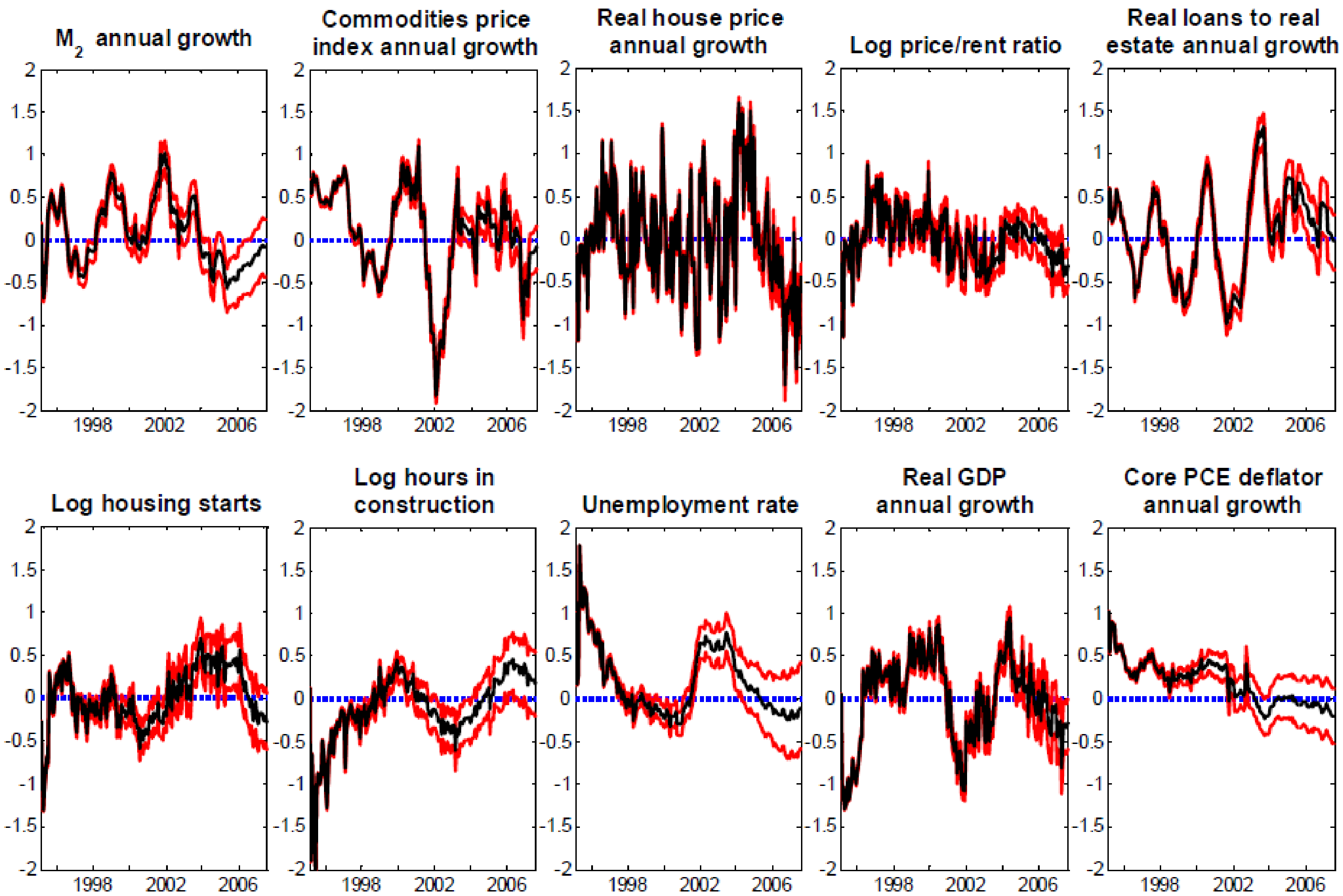

Figure 15 Leeper and Zha's modesty statistic for variables other than the Federal Funds rate, for $K = 0.02$ (medians, and 5-95 percentiles)